Report 93

GEOLOGY OF THE BARCHUMA-KOM AREA

by

R.G. DODSON

Mines & Geological Department
Nairobi

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Geological map of the Barchuma-Kom area (Degree Sheet 29 SW), scale 1:125,000 ..... At end

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PREFACE

The geological field survey of the Barchuma-Kom area was carried out between November 1960 and March 1961 by R.G. Dodson, and was undertaken as part of an overall plan to map the whole country in order to produce geological resource maps. The area covered by the survey falls administratively within the Eastern Province of Kenya where communications and access then, as now, were very difficult.

The geological map of the Barchuma-Kom area was printed and published in 1964; and the subsequent long delay in the publication of the associated report is regretted. The delay has meant that some of the geological nomenclature may appear archaic, but such terminology has been retained in order to maintain consistency with the already-published map. In order to speed up final production of this report, therefore, few editorial changes have been made to the original text.

The report still has much to offer on the details of the geology of a remote and seldom-visited part of Kenya. It contains interesting comments on the distribution and stratigraphy of Mesozoic sediments in the north-east of the country which are still pertinent to present-day hydrocarbon exploration.

J. WACHIRA
Chief Geologist
March 1991

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ABSTRACT

The report describes an area of some 1,200 square miles (3,100 square kilometres) in north-central Kenya, bounded by latitudes 1°00' and 1°30' N, and by longitudes 38°00' and 38°30' E.

Over approximately one-third of the area, Precambrian rocks crop out - mainly metasediments of the 'Basement System' - with a complex of basic and ultrabasic intrusive rocks believed to date from the time of metamorphism of the metasediments.

Jurassic marine sediments occur in two small areas, and are of interest in that they prove Mesozoic marine transgression to have extended much farther to the west than had hitherto been realised.

Several plateaux of basalt, locally capping Tertiary sediments, are believed to be remnants of a once-continuous sheet. The remainder of the area is blanketed by Quaternary superficial deposits.

Detailed petrographic descriptions of the various rock types are given, and the grade of metamorphism of the older rocks is discussed. A detailed account is given of the structure of the area.

The final chapter lists the economic possibilities of the area, which are of low potential except, possibly, for hydrocarbon exploration.

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I. INTRODUCTION

The limits of the Barchuma-Kom area are defined by the meridians 38°00'E and 38°30'E, and by latitudes 1°00'N and 1°30'N. It comprises the quarter degree sheet 29 SW, and is some 1,200 square miles (3,100 square kilometres) in area. For administrative purposes the area is divided into three separate districts. The Samburu District of Rift Valley Province extends into the extreme south-western corner of the area, and the north-western corner falls within Marsabit District of Eastern Province. The remainder lies in Isiolo District, also of Eastern Province. The police post at Kom is administered from the Maralal divisional police post at Wamba. The area was mapped in reconnaissance style, the fieldwork being completed between November 1960 and March 1961.

Population

The area is populated by members of the Boran, Rendille and Samburu pastoral groups. Following the practice of most of the nomadic pastoralists of Northern Kenya, the tribesmen are almost continuously moving in search of grazing for their stock. During the rainy seasons they scatter into the drier parts of the country in search of fresh grazing, returning to areas permanently supplied with water only when all temporary water supplies are exhausted.

Climate and vegetation

The climate is generally hot and dry. The western part of the area between Kom and Solberawawa, with an altitude of up to 2,200 feet (670 m) above sea level, is noticeably cooler than the low-lying plains along the eastern part of the area. No rainfall records are available for this area. However, considering the monotonous, unchanging nature of the country between the eastern part of the area and Habaswein, it is probable that the rainfall statistics of Habaswein also represent the entire region. That station, at an altitude of 1,787 feet (545 m), recorded a yearly average over ten years of 9.34 inches (237.2 mm).

Vegetation in the western part of the area consists mainly of dense thorn scrub. The sand rivers of this region are lined with doum palms and large *Acacia* trees. The lava plateaux Sukela and Barchuma are less densely covered with bush, but support a mat of coarse grass, locally dotted with *Euphorbia*. Eastwards the gently-undulating topography of the Kom region changes to a featureless plain supporting sparse, patchy vegetation of tufted grass and isolated thorn bushes.

Communications

A roughly north-south aligned motorable track connects Barchuma with Archer's Post and Isiolo to the south-west, outside the mapped area. The track is passable to most vehicles but the two sand rivers, Kom and Solberawawa, make passage difficult for vehicles not equipped with four-wheel drive. An east-west track connecting Laisamis with Wajir passes through the northern part of the area. This track has been neglected for some years so it may be assumed that, if no further maintenance is carried out, the road will disappear within a few years.

Maps

The geological map is based on the topographical map sheet 81, series Y633 at 1:100,000 scale. Field evidence was plotted on tracings of air photographs and later transferred to maps on the scale 1:83,333, for mechanical reduction to the printed scale of 1:125,000. Where greater detail was required larger-scale maps were made by plane-table survey. These maps were either reduced to the 1:83,333 scale or, as in Fig. 4, included in the text.

II. PREVIOUS GEOLOGICAL WORK

The Barchuma-Kom area has attracted little attention in the past. The Merti Plateau, part of which is included in the south-eastern corner of the area, is however mentioned by several writers, receiving detailed examination by some. W.H. Broun (1906) described the Erimba (Merti) plateau, stating that it was 'some 20 miles in length, its long axis east and west and its height 300 feet'. I.N. Dracopoli (1913) gave a slightly more detailed description of Merti, describing the plateau as 'the last mountain deserving the name between this place and the sea'. He pointed out that Merti was of volcanic origin and observed that it was roughly oval in shape, the long axis being almost due E-W. J. Parkinson (1920) made the first reconnaissance geological survey of the Northern Province. He traversed to the south, east and west of the present area, and noted that a striking change occurred along a line defined by the disappearance of crystalline and igneous rocks against a featureless plain of sand and loam. It is assumed that this line passes through the Barchuma-Kom area, dividing the eastern and central parts of the area from the exposed rocky regions along the southern and western boundaries. In an unpublished report on a military/geological reconnaissance, H.D. Roberts (1941) stated the belief that the whole of the region east of the Isiolo-Laisamis road was reduced by pre-Tertiary peneplanation. He concluded that the peneplanation produced an extensive conglomerate and sandstone formation, now preserved only locally in original form under later lava flows.

F. Dixey (1948) described certain features of the area in a report on the geology of Northern Kenya. He identified remnants of two erosion surfaces: the 'end-Tertiary peneplain' occupying virtually all of the low-lying country around the Merti plateau, and the 'mid-Tertiary peneplain', represented in the present area by the surface underlying the Merti plateau lava cap. Dixey considered the Merti sediments to be Tertiary, pointing out however that fossil wood present was of indeterminable age.

The area to the south of the Barchuma-Kom area was mapped in 1958/1959 by L.A.J. Williams, whose conclusions appear in Report No. 75 (1966) of the Geological Survey of Kenya.

III. PHYSIOGRAPHY

1. Topography and drainage

The area is divisible into three main physiographic units (Fig. 1): the gently undulating hills along the western and southern margins of the area; the open plains occupying the central, north and eastern regions; and the lava plateaux of Merti, Sukela, and Barchuma.

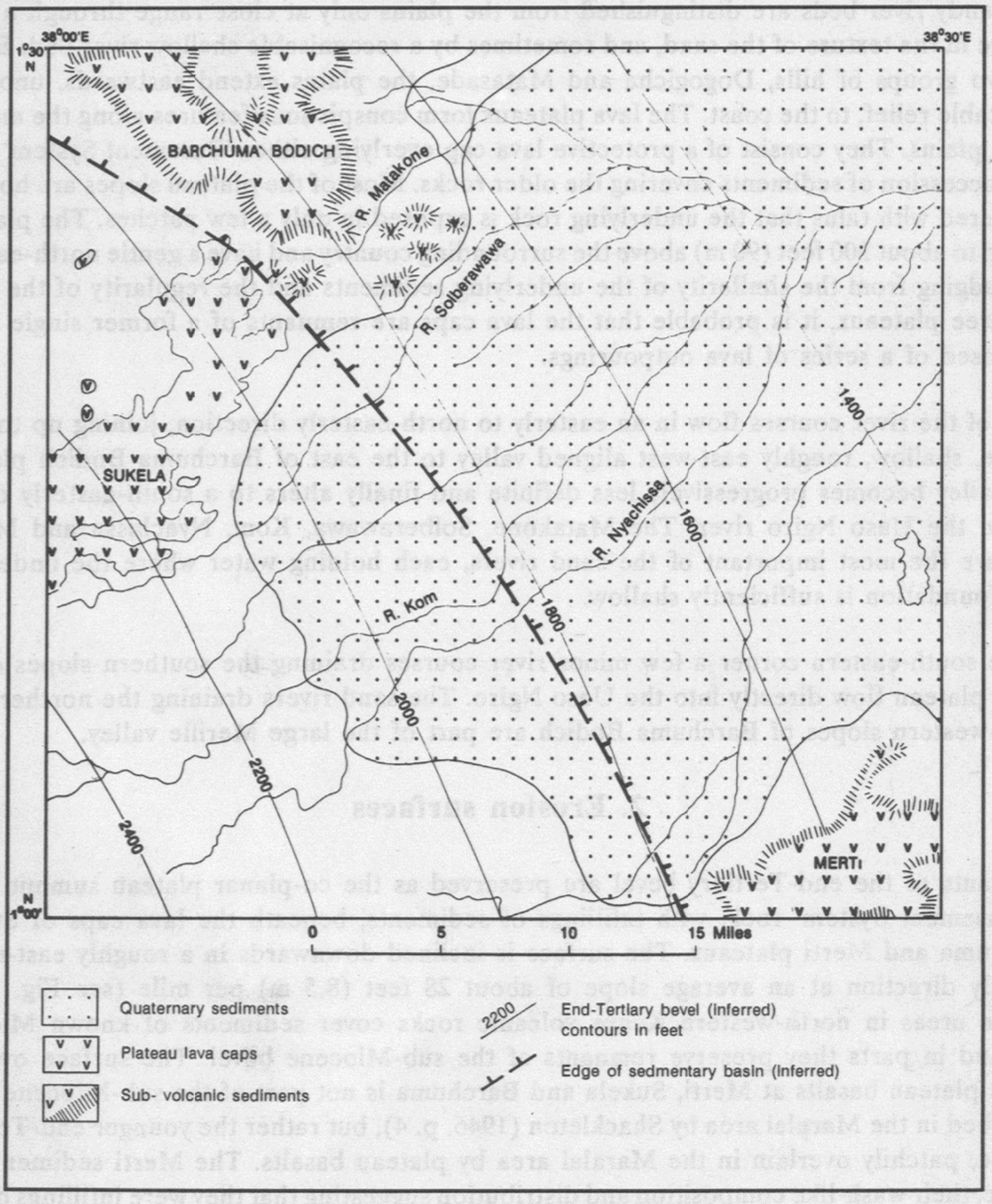


Figure 1 Physiographic divisions of the Barchuma-Kom area

The western and southern parts of the area are composed largely of 'Basement System' rocks, locally intruded by a suite of mafic plutonic rocks and ortho-amphibolites derived from them. These regions are typified by well-dissected, clearly-defined valleys contrasting with gently-undulating interfluves, dotted with rocky hills or granitoid gneiss tors. In the Dalecha area the topography is more rugged. Hills are steep-sided with only patchy vegetation cover, the valleys being choked with soils and rock debris. The dissected, undulating country of the upper Kom valley opens out into a flat, featureless plain stretching as far as the eye can see. The valleys become less well defined and gradually merge into the sandy plains. The sandy river beds are distinguished from the plains only at close range through a slight change in the texture of the sand, and sometimes by a recognisable shallow river bed. Except for two groups of hills, Dogogicha and Matasade, the plains extend eastwards, unbroken by notable relief, to the coast. The lava plateaux form conspicuous features along the margins of the plains. They consist of a protective lava cap overlying either 'Basement System' rocks or a succession of sediments covering the older rocks. Most of the plateau slopes are however so littered with talus that the underlying rock is exposed in only a few patches. The plateaux rise up to about 300 feet (90 m) above the surrounding country and have a gentle north-easterly tilt. Judging from the similarity of the underlying sediments and the regularity of the tilt of the three plateaux, it is probable that the lava caps are remnants of a former single sheet, composed of a series of lava outpourings.

Most of the river courses flow in an easterly to north-easterly direction, joining up to form a wide, shallow, roughly east-west aligned valley to the east of Barchuma Bodich plateau. The valley becomes progressively less definite and finally alters to a south-easterly course to join the Uaso Ngiro river. The Matakone, Solberawawa, Kom, Nyachissa and Muddo Gali are the most important of the sand rivers, each holding water where the underlying rock foundation is sufficiently shallow.

In the south-eastern corner a few minor river courses draining the southern slopes of the Merti plateau flow directly into the Uaso Ngiro. The sand rivers draining the northern and south-western slopes of Barchuma Bodich are part of the large Merille valley.

2. Erosion surfaces

Remnants of the end-Tertiary bevel are preserved as the co-planar plateau summit levels of 'Basement System' rock, with infillings of sediments, beneath the lava caps of Sukela, Barchuma and Merti plateaux. The surface is inclined downwards in a roughly east-north-easterly direction at an average slope of about 28 feet (8.5 m) per mile (see Fig. 1). In certain areas in north-western Kenya volcanic rocks cover sediments of known Miocene age, and in parts they preserve remnants of the sub-Miocene bevel. The surface overlain by the plateau basalts at Merti, Sukela and Barchuma is not part of the sub-Miocene bevel described in the Maralal area by Shackleton (1946, p. 4), but rather the younger end-Tertiary surface, patchily overlain in the Maralal area by plateau basalts. The Merti sediments are deltaic, their wash-like composition and distribution suggesting that they were infillings during the planation of a dissected landscape. The sediments thicken from a roughly north-north-

westerly line passing along the northern edge of the Sukela plateau to the south-west of the Merti plateau. In the Barchuma area the sediments thicken from a thin wedge on the northernmost tip of Sukela plateau to a succession over 100 feet (30 m) thick beneath the lava capping hills between Sukela and Barchuma Bodich. The thickness of the sediments of Barchuma Bodich plateau is not known, as the exposed succession, amounting to nearly 300 feet (90 m), may represent only a portion of the total thickness in that area. It is concluded therefore that before the end-Tertiary planation, tilting, or more probably basin depression, took place. The surface underlying the plateau lava caps is believed to be a product of planation during the late-Tertiary to end-Tertiary period.

Since maturation of the end-Tertiary bevel there has been dissection of the erosion surface and a renewal of minor basin subsidence in the region to the east of the present area. For descriptive purposes the sedimentary basin is referred to as the Habaswein basin or embayment. Quaternary sediments were deposited in the subsiding basin to form a plain surface, the margin of which (Fig. 1) is included in the eastern and central parts of the area. Projection of the end-Tertiary bevel profile eastward shows that the erosion surface would dip below the present plain surface within 10 miles (16 km) of the eastern boundary of the Barchuma-Kom area.

W. Pulfrey (1960) concluded that the extended profile of the sub-Miocene bevel dips below the profile of the more gently-inclined end-Tertiary surface along a morvan line aligned within a short distance of the present area's eastern boundary. In the map accompanying Pulfrey's bulletin the morvan is shown curving around from a roughly east-west direction to an approximate north-south alignment, coinciding roughly with the sedimentary basin. Remnants of the sub-Miocene bevel are absent in the present area, but comparing the slope recorded by Pulfrey and the known profile of the end-Tertiary surface in the present area, it is apparent that the two erosion-surface profiles will meet within about 30 miles (48 km) of the eastern boundary of the area.

IV. SUMMARY OF GEOLOGY

The rock types mapped comprise a metamorphic succession of granulites, gneisses and crystalline limestones of the 'Basement System', intruded by a suite of basic and ultrabasic rocks. Sediments, believed to be of Mesozoic age, form two isolated hills protruding through the superficial deposits in the eastern part of the mapped area. Younger sediments, believed to be late Tertiary in age, form the foundations of two of the three main lava plateaux in the area. Associated with the plateau lavas are feeder dykes and volcanic plugs. Secondary limestones and thin deposits of superficial soils locally overlie the rock formations, but in the central and eastern part of the area the older geological formations are completely hidden by deep accumulations of sand and soil deposits.

'Basement System'

Metamorphic rocks of the 'Basement System', of Precambrian age, are found along the western and southern edges of the area. The succession comprises crystalline limestones and calc-silicate granulites, present as intercalations in the gneisses; rocks of pelitic composition such as sillimanite gneisses and muscovite schists; and semi-pelitic rocks such as biotite gneisses and hornblende-biotite gneisses. The psammitic rocks recorded are quartz-felspar granulites, porphyroblastic gneisses and granitoid gneisses. A small outcrop of migmatite, with a host rock of semi-calcareous composition, occurs in the south-eastern portion of the area immediately west of the Merti plateau. Intercalated bands of amphibolite distributed through the metasedimentary rocks are believed to represent metamorphosed basic intrusive rocks or lavas introduced into the original sedimentary rock succession before the main phase of metamorphism.

The suite of intrusive rocks is characteristically hypersthene-bearing and may constitute the northernmost limit of what is believed to be a belt of such rocks, extending from the southernmost occurrence in the Embu-Meru area, beneath a pile of volcanic rocks, to emerge in the Archer's Post and Chanler's Falls areas. The intrusive body consists of 'cores' of unaltered rock surrounded by shells of completely metamorphosed ortho-amphibolite. In contrast to north-south structural trends of the 'Basement System', the intrusive rocks are folded in an east-west alignment, the trend curving to an approximate west-south-westerly direction at the southern boundary of the area. Both the 'Basement System' rocks and the intrusive rocks are intruded by a variety of pegmatites.

Mesozoic sedimentary rocks

Two hills composed of sediments believed to be of Mesozoic age were mapped. The Dogogicha sediments consist of compact sandstones with shale horizons, while the Matasade sediments com- prise a series of oolitic limestones with fossil horizons, overlain by sandstones.

Tertiary sedimentary rocks

Sediments (the Merti Beds) underlie the lava caps of the Merti and Barchuma Bodich plateaux. They consist of kaolinitic sandstones and conglomerates, and include concretions and nodules of calcrete. They are considered to be of late-Tertiary age.

Volcanic rocks

The lavas capping the three main plateaux, with smaller lava outliers, are considered to be remnants of former compound basaltic lava flows. Feeder dykes and plugs can be lithologically related to the plateau basalts.

Superficial deposits

Gravels, sands and soils patchily cover most of the known rock formations, and form deep accumulations in the central and eastern parts of the area. Gravels derived from the basic intrusive rocks are characteristically dark grey, containing a high percentage of dark heavy minerals. Kunkar or secondary limestone covers some 'Basement System' rocks, particularly those containing lime-rich minerals such as hornblende.

V. DETAILS OF GEOLOGY

1. 'BASEMENT SYSTEM'

For descriptive purposes, the 'Basement System' is described under the following headings:-

(1) Metamorphosed sediments

(a) Calcareous rocks
  (i) Crystalline limestones
  (ii) Calc-silicate granulites

(b) Pelitic rocks
  (i) Sillimanite gneisses
  (ii) Muscovite schists

(c) Semi-pelitic rocks
  (i) Biotite gneisses
  (ii) Hornblende-biotite gneisses

(d) Psammitic rocks
  (i) Quartz-felspar granulites
  (ii) Porphyroblastic gneisses
  (iii) Granitoid gneisses

(2) Migmatites

(3) Meta-intrusive rocks

(a) Amphibolites

The succession of 'Basement System' rocks along the line of section AB on the geological map is as follows:-

Biotite gneisses	200 feet	(61 m)
Porphyroblastic gneisses	200 feet	(61 m)
Granitoid gneisses and amphibolites	4,000 feet	(1229 m)
Porphyroblastic gneisses and sillimanite gneisses ± ...	2,000 feet	(610 m)
Biotite gneisses and amphibolites ±	400 feet	(122 m)

(1) Metamorphosed sediments

(a) Calcareous rocks

(i) Crystalline limestones

Isolated bands of marble occur in the Kubi Aliba area and in the northern sector of the Gersi hills. As is the case in most parts of East Africa, the limestones typically have sharp contacts with contiguous rock bands. In the Kubi Aliba area however a band of limestone situated between two layers of calc-silicate granulite, includes streaks of calc-silicate minerals and has perceptible light and dark grey banding at the marginal contacts.

The limestones are white, pink, or pale grey in colour, with few macroscopic impurities. The most common non-calcareous minerals present are graphite, magnetite, quartz, felspar, muscovite and, rarely, serpentine. Specimen 29/125* from the Gersi hills is typical of the crystalline limestones. It is a coarse-textured pale grey marble, composed of granular calcite with specks of magnetite, quartz grains, muscovite flakes, and rare zircon crystals. Considering their stratigraphical continuity, together with their frequent association with graphitic rocks in other parts of East Africa, these limestones are believed to be of sedimentary origin.

A different origin is ascribed to minor lenses of limestones found in some amphibolite bands. Most of these lenses are of very small size, but an amphibolite band just beyond the north-eastern edge of the Sukela plateau includes a lens about 12 feet (3.7 m) long. Specimen 29/63 from that locality is a coarse-textured reddish-brown crystalline limestone composed of calcite, hornblende patchily replaced by chlorite, magnetite, diopside and quartz. It is assumed that these lenses are metamorphic products of segregations in the original rock, probably formed as a by-product of the decalcification of basic plagioclase.

(ii) Calc-silicate granulites

Lenses of these rocks are abundantly scattered through the 'Basement System' succession in the area. In addition, lenticular to ovoid segregations of calc-silicate composition are widely distributed through the layers of ortho-amphibolites surrounding the suite of plutonic rocks in the Dalecha area.

The calc-silicate granulites vary both in mineral composition and distribution. Generally, the larger bodies occur in the less foliated rock bands, the well-foliated gneisses including a wide variety of calc-silicate bodies, ranging from small ovoid inclusions a few inches long to lenses up to a mile in length. The larger lenses frequently form discontinuous outcrops, pinching out to reappear farther along strike. Due to their superior resistance to erosion, in comparison with the surrounding 'Basement System' rocks, the calc-silicate granulites form striking outcrops of heaps of mottled greenish, reddish or dark grey boulders.

The most common type of calc-silicate granulite is a tough, epidote-rich variety. Specimen 29/38, from a prominent lens immediately south of Kitio hill, is a compact, even-grained, grey to greenish-coloured rock, sparsely spotted with monomineralic segregations of plagio-

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*Numbers prefixed by 29/ refer to degree-sheet specimens in the regional survey collection at the Mines and Geological Department, Nairobi

clase or hornblende. In thin section it is granulitic-textured, composed of pale yellow ish-green epidote, andesine (An_{40}), green hornblende and abundant granules of sphene. Both epidote and sphene are poikilitically enclosed in some of the hornblende grains. Accessory apatite is present. Garnet-rich granulites are nearly as common as the epidote-rich types. They are reddish-brown to maroon-coloured rocks, mottled with white, grey or green minerals. Specimen 29/27, from about 4 miles (6.4 km) south-south-west of Matakone hill, is an even-grained dark maroon rock composed of a sieve texture of pale orange garnets with andesine felspar, epidote, green hornblende, large grains of magnetite and accessory zircon.

Although composed largely of calcium-rich minerals, specimen 29/77 from the Kubi Aliba area shows little similarity to the typical calc-silicate granulites. In hand specimen it is a slightly streaky, compact, greenish-grey rock. In thin section it is allotriomorphic-textured and composed of pale green to medium-green diopside, pale brown garnets, free calcite, scapolite present as the calcium-rich member meionite, quartz, orthoclase and small granules of sphene. The calc-silicate rock from Kubi Aliba occurs as layers on either side of a band of crystalline limestone. A yet more unusual rock of calc-silicate composition forms a low ridge in the Dalecha area, about 2 miles (3.2 km) north-north-east of Chabich hill. The rock has a slightly resinous lustre, and the pale yellow to off-white colour found in many fine-grained crystalline limestones. In thin section 29/85, however, the rock is free of calcite, consisting largely of plagioclase, identified as bytownite (An_{75} to An_{80}), with epidote, quartz and sphene. The presence of abundant quartz and the granularity of texture indicate the metamorphic changes in this rock: it is possible that in its original form it was an igneous rock of the andesite group.

Most of the calc-silicate granulites are considered to be the metamorphic product of an original impure limestone, calcareous sediment, or a calcium-rich igneous rock. The numerous lenses, veins and stringers of calc-silicate composition included in the ortho-amphibolites surrounding the Dalecha intrusive rocks are, however, considered to be calcic segregations produced by the de-calcification of plagioclase during the regional metamorphism of intrusive rocks. Indications of the origin of these minor lenses are provided by certain features connected with their structures. First, they are invariably surrounded by a margin impoverished in calcium-bearing minerals such as diopside, epidote and hornblende. Second, identifications carried out suggest that the plagioclase in these rocks (An_{45} to An_{50}) is slightly more basic than the andesine (An_{35}) typical of the epidote-rich granulites.

(b) Pelitic rocks

(i) Sillimanite gneisses

Two narrow bands of sillimanite-bearing gneisses are useful marker horizons in the tightly-folded succession of the Dakadima anticline. Specimen 29/74, from about 1.5 miles (2.4 km) north of Dakadima hill, is a nearly white, porcellaneous rock composed of sillimanite, quartz, and sphene. Sillimanite occurs in seams winding around the quartz grains and as tufted sheaves. Specimen 29/51, from the more northerly outcrop of sillimanite gneiss, consists of abundant microcline, replacing quartz and plagioclase, and sillimanite, present both as tufts

of needle-like prisms and as medium-sized subhedral to euhedral prisms. Specimen 29/126, from the Gersi hills, similarly contains sillimanite needles and larger individual prisms. Additional minerals in this specimen are porphyroblastic pale pinkish garnets, abundant biotite, orthoclase and quartz. Accessory minerals are magnetite, zircon and rutile.

(ii) Muscovite schists

A single outcrop of muscovite schist is exposed as a narrow band on the upper slopes of a hill south of Kubi Dukessa. The rock is typical of muscovite schists found in the 'Basement System' and described from many parts of Kenya. In hand specimen it is an off-white to pink rock composed of mica and felsic minerals. The abundance of mica, concentrated in seams, imparts characteristic fissility. Outcrops of the schist are marked by discontinuous heaps of micaceous slabs often scattered for some distance around the margins of the layer. Specimen 29/136 from the single solid exposure is composed of partings of muscovite, separating layers of quartz, microcline and oligoclase.

(c) Semi-pelitic rocks

(i) Biotite gneisses

Biotite gneisses comprising numerous textural and mineral variations were collectively mapped as a single lithological unit. The gneisses include slightly-banded horizons, medium-textured homogeneous gneisses, and fissile, schistose rock of pelitic composition. The variations mentioned are less apparent in field exposures than in hand specimens, and significantly they grade or merge into adjacent layers. Specimen 29/48, from about 3 miles (4.8 km) north-east of Kitio hill, is part of a compact homogeneous biotite gneiss which forms low, linear, rocky ridges. It is composed of quartz, plagioclase (oligoclase, An_{15}), microcline (replacing both plagioclase and quartz), biotite, magnetite and accessory garnet, zircon and apatite. The biotite is a dark green variety, occurring as medium-sized flakes aligned in common orientation. Specimen 29/94, from the Kom river bed about 5 miles (8 km) downstream from Kom, is typical of the lightly-banded biotite gneisses. The banding is caused by alternation of dark- and light-coloured layers, dependent on the abundance of biotite in each layer. The felsic layers are often enriched with microcline, suggesting that the banding represents early *lit-par-lit* injection. Biotite gneisses of a more argillaceous composition, such as specimen 29/42 from just over 2 miles (3.2 km) south of Solberawawa waterhole, are usually found as lenses or discontinuous bands in the massive biotite gneisses. It is a dark grey, somewhat schistose rock composed of green biotite, quartz, orthoclase, oligoclase, ilmenite, sphene and abundant accessory apatite. A similar rock, specimen 29/43 from about 1 mile (1.6 km) east of Solberawawa waterhole, includes small amounts of replacive microcline.

(ii) Hornblende-biotite gneisses

The only exposure of hornblende gneiss in the area is a small hill about 2 miles (3.2 km) south of the Kubi Aliba hills. Locally biotite gneisses include small lenses of hornblende enrichment, similar to the minor calc-silicate inclusions already described. Specimen 29/86, from the hill south of Kubi Aliba, is a strongly gneissic allotriomorphic-textured pale grey rock with patches of light mauve-coloured felspar, and flecked with streaks of dark minerals.

On weathered surfaces most of the biotite has been converted to vermiculite. The rock consists of potash felspar, plagioclase, hornblende, biotite, quartz and accessory minerals. The potash felspar is present both as small grains in a sponge-like texture, and larger subhedral grains with myrmekitic inclusions. Oligoclase (An_{15}) occurs as abundant medium-sized grains often with myrmekitic marginal intergrowths. Green hornblende and biotite are distributed throughout the rock, with slight concentration along narrow seams. Accessory minerals present are magnetite, apatite and zircon.

(d) Psammitic rocks

(i) Quartz-felspar granulites

Rocks of even-grained granulitic texture, primarily of quartzo-felspathic composition and texture and containing only small amounts of dark minerals, occur as rare but distinctive lenses in the 'Basement System' rocks. They show no mineral or textural relationships with adjacent bands of rock, but can be matched with similar granulites from other parts of Kenya. Typically the quartz-felspar granulites are pale grey-pinkish in colour, or when stained by iron oxide are maroon-coloured, and composed essentially of quartz and felspar. In field exposures these granulites resemble quartzites, their high felspar content being recognizable only on close examination. Specimen 29/31, from about 3 miles (4.8 km) west of Solberawawa waterhole, is an even-grained, coarse-textured rock, composed of microcline, quartz and oligoclase. The only non-felsic minerals present are a few small flakes of muscovite and grains of a highly altered ferromagnesian mineral. The patchy maroon discolouration of the rock is due to staining of slightly-weathered felspar grains by iron oxides leached from the altered dark minerals, and redeposited along the crystal cleavages and in the interstitial spaces.

A narrow band of fissile, even-grained rock is included in the Dalecha intrusive rocks, about 2 miles (3.2 km) east of Chabich hill. The rock band is nearly vertically inclined and is considered to be an undigested remnant of the 'Basement System' rocks displaced by the plutonic rocks. In hand specimen it is a medium-grained, equigranular, pale grey fissile rock, characterized in the field by its flaggy habit. In thin section (specimen 29/82) it is seen to be a granulitic-textured rock composed of a honeycomb of equidimensional microcline grains, abundant green hornblende patchily replaced by chlorite, epidote, specks of ilmenite, sphene and accessory zircon. This unit includes patchy copper mineralization. Most of the mineralization consists of no more than isolated specks of malachite, but a single locality, about 8 feet (2.4 m) long and approximately 2 feet (0.6 m) wide, contains concentrated mineralization of bornite and secondary carbonates. The host rock in the mineralized sector contains calcium enrichment, shown by the appearance of abundant epidote. Specimen 29/83, a sample showing the copper mineralization, includes irregular patches of bornite surrounded by margins of replacive malachite, the latter being present also as veins through the rock. Azurite and chalcopyrite, not observed in the thin section, are present as rare constituents in the hand specimen.

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(ii) Porphyroblastic gneisses

Coarse-textured massive rocks, characterized by an abundance of well-developed porphyroblastic felspars, form most of the rock outcrops of the high ground between Kom and Solberawawa. The porphyroblastic gneisses vary slightly in colour, but are constant in their textural and mineral composition. Specimen 29/47, from approximately half-way between Kom and Solberawawa waterhole, is an allotriomorphic-textured rock composed of microcline porphyroblasts set in a granoblastic matrix of quartz, biotite, hornblende and accessory apatite. The microcline is sometimes perthitic and replaces both the plagioclase (An_{15}) and quartz. Biotite is the more common mafic mineral, often forming marginal concentrations around the felspar porphyroblasts. Magnetite is a common constituent, usually present as medium-sized idiomorphic grains sparsely distributed through the rock, as typified by specimen 29/39 from an exposure about two and a half miles south of Solberawawa waterhole.

(iii) Granitoid gneisses

Most of the tors and prominent rock slabs in the area, such as Kitio and Dakadima, are composed of massive granitoid gneiss. Kitio hill is a large inverted basin-shaped slab of coarse-textured gneiss around which less competent rock bands were folded. Dakadima is a conical hill made up of heaps of large rounded boulders. In slabs of rock found on these hills the granitoid gneiss is seen to be remarkably homogeneous, showing only slight variations of texture, such as rare biotite-rich schlieren and patchy veins of permeation pegmatites.

Specimen 29/21, from Nagrokwe hill, which is typical of the granitoid gneisses, is a coarse-grained, granitic-textured rock showing only slight preferred orientation in the hand specimen. It is composed of microcline, oligoclase and quartz, with medium-sized magnetite grains and small shreds of green biotite. Microcline is often perthitic and frequently forms myrmekitic intergrowths. The granitoid gneisses are typically leucocratic. Biotite is usually present but, as typified in specimen 29/21, occurs as evenly-disseminated small shreds, seldom concentrating in seams or trains of mica flakes.

(2) Migmatites

Migmatization on a small scale can be observed in most foliated rocks in the area. In the biotite gneisses patches of contorted lenses and laminae composed of granitic material exhibit parallelism with the biotite-rich host rock.

The granitoid gneisses and porphyroblast gneisses include faint traces of banding considered to be relics of migmatite texture, largely obscured by the effects of granitization. Primitive migmatization can also be observed in small patches along the marginal contacts of the ortho-amphibolites exposed in the Nyachissa valley. In these essentially localised patches, the amphibolite is intruded by a variety of pegmatite veins. Despite the weathered condition of the exposures, it is possible to recognize the alteration of hornblende to biotite, and the enrichment of felsic minerals in narrow zones.

A small outcrop of rock in the south-eastern sector of the Gersi hills is considered to be the only true migmatite in the area. Specimen 29/127 from that outcrop is composed of a compact granulitic-textured grey to bluish host rock, mottled with abundant pale pinkish to lilac-coloured felsic veins, lenses and stringers. The veins occur in roughly parallel alignment, concordant with the foliation. Lenses and variable-shaped stringers are usually oriented obliquely or at right-angles to the strike. The felsic veins account for about 20% of the total rock composition. The host rock is composed of an equigranular mosaic of quartz, rare untwinned oligoclase, abundant bluish-tinted ilmenite, hornblende, diopside and accessory zircon. Patchy microcline development occurs along the margins of the host rock and felsic veins, but is rare elsewhere in the granulite. The felsic veins are typical of migmatite pegmatites, being composed almost entirely of microcline and quartz, with small amounts of ilmenite and hornblende, presumably incorporated from the host rock. The Gersi hills migmatite is unusual in that the compact granulitic texture of the host rock, with a predominantly quartzose composition, is normally proof against migmatization, the typical migmatites of the 'Basement System' being gneissose rocks of pelitic or semi-pelitic composition.

(3) Meta-intrusive rocks

(a) Amphibolites

While amphibolites occur in various parts of the 'Basement System' metasedimentary succession, regional mapping in Kenya has shown that they are most abundant in certain stratigraphic horizons, particularly in a series of gneisses of predominantly semi-pelitic to psammitic composition underlying the Turoka Series. The 'Basement System' rocks of the Barchuma-Kom area are believed to belong to this series. The amphibolites are intercalated with the gneisses as variable-sized but distinct bands, usually persisting for a considerable distance. It is presumed that the amphibolites are the metamorphosed products of original igneous rocks of basic composition, a belief strengthened by the similarity of known ortho-amphibolites of the Dalecha suite of rocks, and the amphibolites of the 'Basement System' gneisses.

Amphibolites are rarely well exposed except in well-dissected valleys, as they are more susceptible to weathering than the 'Basement System' metasediments of the area. Their presence is however often indicated by minor surface encrustations of kunkar limestones along their strike. They are typically dark grey to greenish-grey coarse-textured rocks, usually of a somewhat schistose nature, with a composition falling within the plagioclase amphibolite class. They are composed essentially of plagioclase, with a composition variable from An_{30} to An_{45}, and green hornblende, with apatite as a constant accessory mineral. Iron ore and zircon are common accessory minerals, as in specimen 29/64, a typical amphibolite from north-east of the Sukela lava plateau. In specimen 29/28, from Solberawawa waterhole, the hornblende is partly replaced by green biotite. Quartz and calcite are present as secondary minerals. Specimen 29/32, from about 3 miles (4.8 km) west of Solberawawa waterhole, which is an amphibolitic rock with relict igneous texture, includes diopside and the calcic scapolite, meionite.

The amphibolites usually have sharp, clearly-defined margins with the 'Basement System' metasediments. To the north-east of Sukela plateau, however, a broad band of amphibolite has a diffuse margin, suggesting contact hybridization between the amphibolite and biotite gneisses. Specimen 29/61 from the hybrid zone is a coarse-textured, pale grey, strongly-gneissic rock, composed of plagioclase (An_{25}), quartz, ilmenite partly replaced by sphene, diopside, pale pinkish garnets and small idiomorphic grains of staurolite.

2. PLUTONIC ROCKS

A large portion of the southern part of the area is occupied by a suite of plutonic rocks described for the purposes of this report as the Dalecha plutonic rocks. They extend southwards into the Chanler's Falls area (Williams, 1966) where they are overlain by a pile of volcanic material. Plutonic rocks exposed in the Meru and Embu districts, which show close textural and mineral similarities with the Dalecha rocks, have been described in detail by Pulfrey (1946), Schoeman (1951) and Bear (1952). Those rocks may be the southern extension of a single plutonic belt stretching from the Barchuma-Kom area to the Embu district, the central part being covered by volcanic rocks (see Fig. 2).

The age relationship between the 'Basement System' and the plutonic rocks is not clear and several writers have discussed the ages of similar hypersthene-bearing rocks in various parts of the world (see Groves, 1935, p. 200). The writer considers the Dalecha rocks to be intrusive into the 'Basement System', as opposed to the other possibility, that the 'Basement System' was deposited and later folded against a pre-existing plutonic mass. It must be admitted, however, that there is a puzzling absence of an aureole of contact metamorphism between the 'Basement System' rocks and the plutonic rocks. The contact between the two rock groups is rarely exposed, but a basic intrusion of such dimensions would be expected to produce a metamorphic zone extending well into the outcropping 'Basement System' rocks in the Nyachissa valley. It may, however, be argued that since the intrusive rocks exhibit the effects of regional metamorphism, contact metamorphism in the 'Basement System' rocks has been obscured or even obliterated by the subsequent regional metamorphism. Alternatively, if emplacement of the plutonic rocks took place after high-grade regional metamorphism, the effects of thermal metamorphism in the metasediments would be limited. D.C. Knill and J.L. Knill (1960, p. 300) observed that thermal metamorphism induced by the emplacement of a granodiorite body in high grade metamorphic rocks was confined to development of porphyritic biotite, with small amounts of cordierite and muscovite. Evidence indicating that the 'Basement System' predates the plutonic suite is provided by the following factors. First, the Dalecha intrusive suite of rocks has apparently displaced the 'Basement System' rocks, bulging the metasediments from a roughly north-south regional strike, in the western part of the Barchuma-Kom area and near the Merti plateau, to the approximate east-west alignment of the exposed gneisses in the southern part of the Muddo Gali valley. Second, the basic intrusive rocks, with their metamorphosed derivatives, appear to be folded against the 'Basement System' mass, their fold axes curving from an approximate east-west alignment to a north-easterly direction at their western marginal contact with the pre-existing

north-south striking 'Basement System' rocks. (For more detailed discussion of structures, see Chapter VII). Finally, at least three dyke-like intrusive bodies similar to the Dalecha norites and gabbros intrude the 'Basement System' rocks in the Nagrokwe area, north-west of Sukela plateau. Pulfrey (1946, p. 67) and Schoeman (1951, p. 7) considered the hypersthene-bearing intrusive rocks of the Meru district to invade the 'Basement System'.

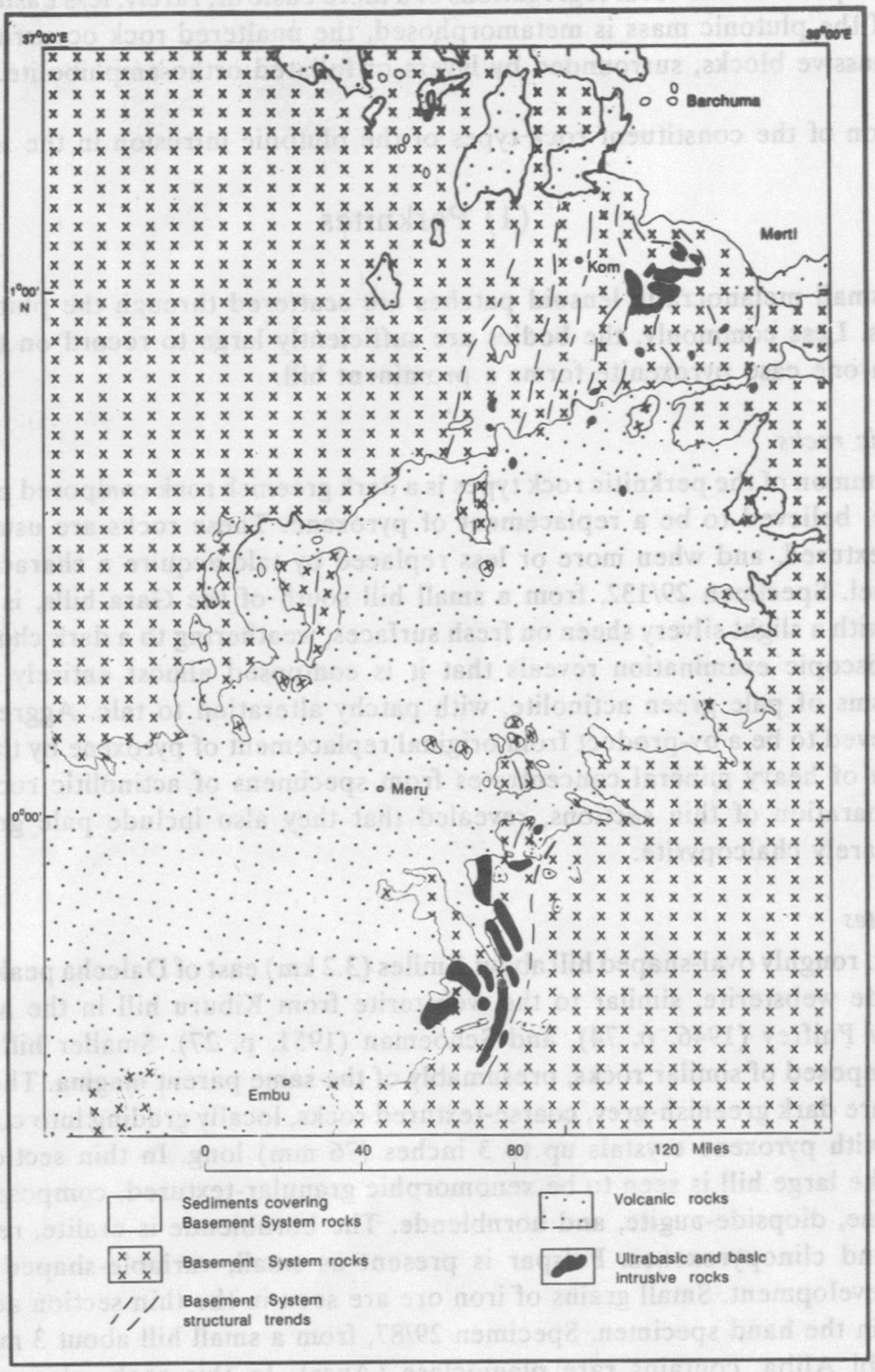


Figure 2 Sketch map showing the regional distribution of basic and ultrabasic rocks

The intrusion of the suite of plutonic rocks is therefore believed to have taken place at the close of the 'Basement System' orogeny, following the main tectonic episode but prior to the final phase of regional metamorphism.

The suite of plutonic rocks comprises a variety of rock types, divisible into those of gabbroidal or noritic composition and local segregations of a more basic or, rarely, less basic composition. The bulk of the plutonic mass is metamorphosed, the unaltered rock occurring in pod-like lenses or massive blocks, surrounded by layers of foliated ortho-amphibolite.

A description of the constituent rock types of the plutonic intrusion in the area follows.

(1) Perknites

Numerous small melanocratic lensoid patches are scattered through the plutonic rocks as segregations. Less commonly, the bodies are sufficiently large to record on the geological map, and in one case pyroxenite forms a prominent hill.

(i) Actinolitic rocks

The most common of the perknitic rock types is a dark greenish rock composed predominantly of actinolite, believed to be a replacement of pyroxene. These rocks are usually schistose to fibrous-textured, and when more or less replaced by talc acquire a characteristic soapy or greasy feel. Specimen 29/132, from a small hill south of the Gara hills, is a flaky, pale green rock with a slight silvery sheen on fresh surfaces, weathering to a dark chocolate-brown crust. Microscopic examination reveals that it is composed almost entirely of fibrous to massive prisms of pale green actinolite, with patchy alteration to talc. Aggregates of iron ore are believed to be a by-product from original replacement of pyroxene by the amphibole. Examination of heavy mineral concentrates from specimens of actinolitic rock too friable for the preparation of thin sections, revealed that they also include pale green chlorite, pyrite and rarely chalcopyrite.

(ii) Pyroxenites

A prominent, roughly oval-shaped hill about 2 miles (3.2 km) east of Dalecha peak is composed of hornblende websterite, similar to the websterite from Kiburu hill in the Meru district, described by Pulfrey (1946, p. 74), and Schoeman (1951, p. 27). Smaller hills around the mass are composed of similar rocks, presumably of the same parent magma. The hornblende websterites are dark greenish-grey, coarse-textured rocks, locally grading into coarser-textured patches with pyroxene crystals up to 3 inches (76 mm) long. In thin section, specimen 29/91 from the large hill is seen to be xenomorphic granular-textured, composed essentially of hypersthene, diopside-augite, and hornblende. The hornblende is uralite, replacing both the ortho- and clinopyroxenes. Felspar is present as small, variable-shaped grains, with interstitial development. Small grains of iron ore are seen in the thin section and pyrrhotite is abundant in the hand specimen. Specimen 29/87, from a small hill about 3 miles (4.8 km) south of Kubi Aliba, contains rare plagioclase (An_{70}). In this rock, pleonaste spinel is abundant, forming dactyllic intergrowth textures, often against a pale brownish, mildly-

pleochroic hornblende, and also as marginal intergrowths around the plagioclase. Olivine is present as medium to large grains, usually occupying the cores of groups of mafic minerals such as hypersthene.

(iii) Peridotites

Only one olivine-bearing rock of peridotite composition was discovered. It occurs as an isolated lensoid body included in the ortho-amphibolites about 1 mile (1.6 km) north-west of Dalecha trigonometrical beacon. The peridotite is a tough, coarse-textured coppery-brown rock, sparsely flecked with small patches of felsic material. Microscopic examination of peridotite, specimen 29/70, reveals that it is composed of xenomorphic grains of olivine, heavily veined with magnetite and replacive serpentine, hypersthene, plagioclase (An_{65}) and green pleonaste spinel. The olivine is optically negative with an estimated optic angle of 83°. The olivine grains are separated from plagioclase by kelyphitic veins composed of hypersthene and dactyllic intergrowths of hypersthene and spinel. Some of the olivines are surrounded by as many as three marginal coronas. Secondary calcite patchily replaces the plagioclase.

Numerous lenses of serpentinite are scattered about the Dalecha hill area and, less commonly, are found in the area south-west of Kubi Dukessa. From the appearance of the relict textures suggestive of original olivine in most of the specimens, it is probable that the serpentinites are alteration products of peridotites. They are typically dark brown to maroon in colour, sometimes flecked with dull yellow, and usually have the characteristic mottling of serpentine. Specimen 29/72, from a large lens near Dalecha beacon, is composed almost entirely of serpentine with irregular aggregates of iron ore, characteristic as a by-product precipitate of serpentinization of olivine. Most of the serpentinites are cut by a network of magnesite veins.

(2) Gabbros

Mesocratic coarse-textured rocks of gabbroidal composition occupy the outer edges of the Dalecha plutonic complex in the Chabich area, and are also exposed in the Kubi Dukessa area. In the Chabich area they appear to be older than the noritic rocks, but the age relationships of the two main types of basic intrusives is relative, there being every indication that they belong to a single complex plutonic phase. In the field the gabbros are distinguishable from the more common noritic rocks as they are usually coarser in grain and lighter in colour. The gabbros are generally of bojitic composition, primary hornblende taking the place of clinopyroxenes. In some of the gabbros, however, the amphibole present is uralite, replacing the pyroxenes.

Specimen 29/84, from about 2 miles (3.2 km) north-east of Chabich, is a typical coarse-textured, mesocratic gabbro. Weathered surfaces are coated with a pale brown crust, dotted with dark lumps of mafic minerals, much like currants in a cake. In thin section it is seen to be hypautomorphic granular-textured, composed of twinned plagioclase (An_{75}), partly uralitized pale greenish diopsidic pyroxene, primary hornblende, and the accessory minerals apatite

and rutile. Specimen 29/81, from about 1 mile (1.6 km) north-north-east of Chabich, is an example of a more melanocratic bojitic gabbro. It is composed of pale green hornblende, partly replaced by actinolite, rare enstatite, plagioclase (An_{70}), dark green pleonaste spinel, iron ore and rare accessory apatite. The mafic minerals tend to be aggregated in rosette textures. The hornblende grains include fine-textured swarms of schiller inclusions, suggesting that although the amphibole does not have the fibrous habit of uralite, it may be derived from original pyroxene. Spinel is present both in marginal intergrowths with hornblende and as irregular grains included mainly in the hornblende, a tendency noted by Pulfrey (1946, p. 72). Chalcopyrite was identified in heavy mineral concentrates prepared from the specimen.

A dyke-like intrusion of gabbroidal composition is exposed on the Barchuma-Koiya road north-west of Matakone hill, where it intrudes a broad band of granitoid gneiss. In hand specimen the rock bears close resemblance to the Dalecha gabbro. Specimen 29/22 from the dyke is a medium-grained mesocratic rock of xenomorphic granular texture composed of plagioclase (An_{60}), hornblende, pale green diopside, scapolite, secondary calcite and accessory apatite. The scapolite is the calcic variety, meionite, believed to be a high temperature alteration of the labradorite.

(3) Norites

The bulk of the Dalecha plutonic rocks are norites, locally including sufficient clinopyroxene to qualify for classification as hyperites. The norites are typically dark, heavy rocks of medium to coarse grain. In the folded layers of norite south of Dalecha peak the felspars have the characteristic lavender colour described by Williams (1966, p. 26) and Jennings (1967, p. 27) in reports on the contiguous areas to the south of Barchuma-Kom. Elsewhere the plagioclase is pale grey to dirty white, or less commonly, as in the minor intrusives in the Nagrokwe area, it is deep greenish-blue in colour.

Specimen 29/55, from about 2 miles (3.2 km) south-south-west of Dakadima, is an example of the melanocratic bojitic norites. It is a dark grey hypautomorphic-textured rock, composed essentially of hypersthene, plagioclase (An_{65}), olivine, uralite, spinel and accessory biotite. The hypersthene is present as xenomorphic grains, often rimmed with uralite. Where in contact with plagioclase the pyroxene forms dactyllic intergrowths with green pleonaste spinel. The uralite surrounding hypersthene is pale bluish-green, but where replacement is complete and the amphibole is crowded with schiller inclusions, it grades into a greenish-brown variety of uralite. Olivine grains are usually surrounded by a margin of hypersthene, even when they are included in amphibole grains. The biotite occurs as small strongly pleochroic flakes: X = dark reddish-brown, Y = clear brown, Z = pale yellow. Specimen 29/95, from the tightly-folded banded norites about 2 miles (3.2 km) south-west of Dalecha peak, is a mesocratic type, with lavender-coloured plagioclase. In thin section there is little indication of the cause of the discolouration of the plagioclase (An_{58}), except that the felspars are crowded with minute inclusions. In specimen 29/26, a hypersthene bearing noritic dyke rock from about 3 miles (4.8 km) south-south-west of Matakone hill, the felspars are greenish-blue in

colour. Microscope examination of the thin section reveals that the plagioclase is crowded with pale greenish blebs, believed to be zoisite derived from felspar. Spectrographic tests carried out by C.G.B. Du Bois, Petrologist of the Mines and Geological Department, Nairobi, revealed that the rock contains an unusually high copper content, which is possibly responsible for the bluish tint of the felspars. Biotite in this specimen occurs as large flakes.

Hyperites, or norites in which orthopyroxene and clinopyroxenes occur in roughly equal amounts, are as abundant in the area as true norites. They form the massif of Dalecha peak and surrounding hills, and also occur as segregated bands in the noritic rocks. In the field, there is little to distinguish hyperite from norite, the two types frequently grading into each other within a broad zone. Similarly, microscope examination of variations of norites and clinopyroxene-enriched noritic rocks shows a variety of gradational stages. In specimens 29/71 from Dalecha, and 29/101 from about 3 miles (4.8 km) south-east of Kubi Aliba, the ortho- pyroxene is hypersthene with weak pleochroism from pale pink to pale green. Optic axial angles were estimated to be 78-81°. Typical of its habit in most of the plutonic rocks the hypersthene occurs both as xenomorphic to subhedral grains, and in semi-fibrous to granular habit, forming the innermost corona margins about olivine grains. The monoclinic pyroxene is a pale greenish augite, with estimated optic axial angles of approximately 57-59°, maximum extinction angles being of the order $c \wedge Z$ 48-50°. Olivine in 29/101 is partly altered to yellow-brown bowlingite. The amphibole of 29/71 is hornblende, pleochroic from yellow to reddish-brown. In 29/101 the amphibole is pale greenish uralite, present as marginal replacement of the pyroxenes.

(4) Anorthosites

No occurrences of massive anorthosite were mapped. In the folded plutonic rocks south of Dalecha peak, localised banding is made up of dark noritic rock with alternating layers of anorthositic composition. The felsic bands are seldom more than 3 inches (76 mm) wide, their pale mauve colour contrasting with the dark noritic bands. The banding is nearly vertical, following the strike of the local folding. Stewart (1946, p. 490) considered comparable banding in the Belhelvie plutonic complex to be due to gravital differentiation, the vertical alignment caused by late tilting.

Specimen 29/96, from the banded rocks south of Dalecha, is a lavender-coloured leucocratic rock, speckled with sparse aggregates of pyroxene and grains of bluish-lustred ilmenite. In thin section, it is seen to be inequigranular allotriomorphic-textured, composed of labradorite (An_{60}) with green diopside and small specks of ilmenite.

(5) Diorites

West of the Muddo Gali sand river the only known band of diorite in the area is exposed on the upper slopes of a prominent hill. The diorite is a coarse-textured, pale grey rock with faint banding. Specimen 29/135 is xenomorphic granular-textured, showing slight strain effects in some of the larger plagioclase grains. The plagioclase is andesine (An_{47}), some

of the grains containing more basic cores of An_{50}, the marginal shells being An_{45}-An_{47}. The ferromagnesian minerals present are pale green hornblende, patchily altered to chlorite, euhedral grains of pale yellow-green epidote and granular sphene, with a few fine shreds of brown biotite. Small granules of epidote and patches of calcite are by-products of saussuritization of the plagioclase.

(6) Ortho-amphibolites

The Dalecha plutonic complex is composed of cores of gabbroidal and noritic rock surrounded by ortho-amphibolites. The amphibolites are considered to be the products of regional metamorphism, which however did not effect complete conversion of the original plutonic mass. While alteration of plutonic rock to ortho-amphibolite is abrupt, with little or no intermediate zone, structural features such as banding are often traceable from the unaltered rock into the amphibolite. Relict igneous textures in the amphibolites are rare.

Specimens 29/66, from just over a mile (1.6 km) south-east of Dakadima hill, and 29/75, from the Nyachiassa waterhole, are representative of the ortho-amphibolites. They are well-foliated, often fissile, dark greenish-grey rocks. In thin section they have the allotriomorphic, somewhat schistose textures typical of the amphibolites intercalated with 'Basement System' rocks throughout East Africa. They are composed essentially of green hornblende and plagioclase (An_{35}) with ilmenite, sphene (in 29/66), quartz (in 29/75) and the accessory minerals apatite and zircon.

3. MINOR FELSIC INTRUSIVES

(1) Aplites

Aplites are uncommon in the area. They intrude 'Basement System' rocks and the Dalecha plutonic rocks as parallel-sided discordant veins and stringers up to 8 feet (2.4 m) thick. In hand specimen they are grey, pink to reddish-coloured rocks of fine grain. A narrow band of fine-grained aplite with flaggy habit is exposed in the northern slopes of an isolated hill immediately west of the Muddo Gali valley. The linear outcrops of the aplite cut obliquely across banding in the local plutonic rocks. The aplite has a compact, slightly greasy appearance, produced by the presence of fine flakes of bluish-green chlorite. The flaggy nature of the aplite is imparted by the presence of abundant flakes of clear muscovite. In thin section specimen 29/133 is a fine-grained, nearly equigranular, aplitic-textured rock, composed of equidimensional quartz and orthoclase felspar grains, skeletal muscovite flakes enclosing quartz and felspar, pale green chlorite, ilmenite and sphene. Accessory apatite is present as minute idiomorphic grains. Specimen 29/62, an aplo-granitic vein intruding a broad amphibolite band exposed along the north-eastern margin of Sukela Plateau, is considerably coarser grained than the other aplites in the area. It is aplitic-textured and composed of orthoclase, plagioclase (An_{25}) patchily intergrown with quartz, small flakes of green biotite and the accessory minerals garnet, zircon, and apatite.

(2) Pegmatites

Pegmatites are abundantly scattered through the area, intruding both 'Basement System' rocks and the Dalecha plutonic rocks. They are divisible into two main types, simple pegmatites and complex pegmatites.

Simple pegmatites, characterized by their homogeneity of texture and composition, vary from a few inches to about 20 feet (6 m) in thickness. Segregation pegmatites occur as lenses and patches. They are best developed in the more compactly-folded semi-pelitic gneisses, and along the marginal contacts of the ortho-amphibolites. Specimen 29/109, from near Nyachissa waterhole, is from a coarse-textured, nearly ovoid-shaped pegmatite body about 14 feet (4.3 m) long. In hand specimen, it is composed of turbid albite, of a pale salmon to pinkish colour, clear replacive microcline with quartz, small shreds of chloritized hornblende and idiomorphic to subhedral grains of magnetite. Permeation pegmatites are best developed in the granitoid gneisses and porphyroblastic gneisses, where they occur as felsic veins and lenses seldom including any dark minerals, but often surrounded by a narrow margin enriched in ferromagnesian minerals. On Kitio hill, a large permeation pegmatite includes idiomorphic hornblende crystals up to several inches long. The permeation pegmatites are either homogeneous, with a coarse-textured monomineralic composition, or medium-textured but including clusters of coarse microcline porphyroblasts. The largest segregation pegmatite was found in a low-lying slab of granitoid gneiss about 5 miles (8 km) south-east of Solberawawa waterhole. The pegmatite is about 9 feet (2.7 m) long and is composed of blocky pink felspar containing patches of quartz, idiomorphic prisms of hornblende and rare magnetite. Specimen 29/52, from the blocky felspar centre, is composed of perthitic microcline and included quartz. The microcline is crowded with minute inclusions of a mineral with a fine prismatic habit and rhombic cross-sections, probably an amphibole. The simple intrusive pegmatites are characterized by their regular parallel-sided form. They intrude both 'Basement System' metasediments and the Dalecha plutonic rocks. They are even-textured, coarse-grained intrusive bodies with only slight variation of the essential mineral components. The most common type is an unmineralized coarse-textured pegmatite, such as specimen 29/40 from 3 miles (4.8 km) south-south-west of Solberawawa waterhole. It is composed of microcline perthite with only rare specks of iron ore and accessory apatite. About 3 miles (4.8 km) south of Kubi Dukessa, pegmatites intruding the plutonic rocks have varying amounts of muscovite. The mica occurring in books up to 2 inches (51 mm) across is scattered haphazardly through the pegmatites. Approximately 2 miles (3.2 km) south of Kubi Aliba a single pegmatite contains a few prisms of bluish-grey corundum.

Complex pegmatites are locally abundant in the area, several forming outcrops sufficiently large to record on the geological map. The largest complex pegmatite forms Chabich hill, while similar pegmatites are exposed in the Kubi Aliba area and to the south-west of Dakadima hill. In the field, quartz cores of the complex pegmatites are easily mistaken for giant quartz veins as they form massive linear slabs of milk-white quartz, protruding through a mantle of weathered rock fragments that obscures the marginal zones of the pegmatite body. The quartz core is particularly resistant to erosion and forms prominent rocky hills in areas

such as Kubi Aliba long after other rock types have been removed by erosion. The Chabich pegmatite is made up of the following components:-

Outer zone: Albite with included muscovite, biotite, magnetite, epidote and patches of calcite.

Inner zone: Myrmekite with blocky subhedral aggregates of microcline. Included epidote, magnetite and muscovite are coarser in texture than the minerals of the outer zone, and tend to be concentrated along the margins of the innermost core.

Core: Massive white quartz containing rare specks of magnetite, small flakes of muscovite and a few blocky microcline crystals.

(3) Quartz veins

Small quartz veins and lenses up to 2 feet (0.6 m) wide are common in the area, cutting both 'Basement System' sediments and locally the plutonic rocks. The veins are composed of nearly clear to lightly-stained quartz. They are devoid of mineralization, except for rare specks of ore.

4. DYKE ROCKS

Dykes are found in most parts of the area not covered by superficial deposits. They tend to follow a roughly north-south alignment or, less commonly, an approximate east-west direction. Most of the smaller dykes are highly weathered.

A stockwork of dykes with a parent boss is exposed at Barambate waterhole in the Matakone valley. The dykes are either vitrophyric or hemicrystalline-textured. Specimen 29/19 is a dark grey microporphyritic basalt, composed of a groundmass of iron ore, labradorite laths and interstitial glass, with idiomorphic olivine and augite phenocrysts.

In contrast, specimen 29/33, from the Solberawawa valley, is a coarse-textured dolerite with a sub-ophitic texture. It is composed of labradorite felspar laths, neutral-coloured augite grains, brown barkevikitic hornblende, idiomorphic olivines and dendritic skeletal aggregates of iron ore. Calcite is present as a secondary replacive mineral. Accessory apatite is present.

An east-west aligned teschenite dyke outcropping about 2 miles (3.2 km) south of Matakone hill may belong to the volcanic phase responsible for the eruption of the two analcime basalt plugs of Sukela. Specimen 29/25 from the dyke is a medium-textured porphyritic rock composed of a groundmass of analcime, barkevikite and iron ore, with idiomorphic phenocrysts of augite and olivine. The augite is strongly zoned, and has the mauve colour characteristic of pyroxenes in teschenites. The olivine is largely replaced by pale greenish antigorite.

5. SEDIMENTARY ROCKS

(1) Sedimentary rocks of Mesozoic age

Two groups of hills, Dogogicha near the eastern boundary of the area and the Matasade hills about 4 miles (6.4 km) east of the north-eastern boundary, are composed of sediments of an age hitherto known only in north-eastern Kenya and in the coastal region. The relationship between the Matasade limestones and other limestones of Jurassic age in Kenya is illustrated in Fig. 3.

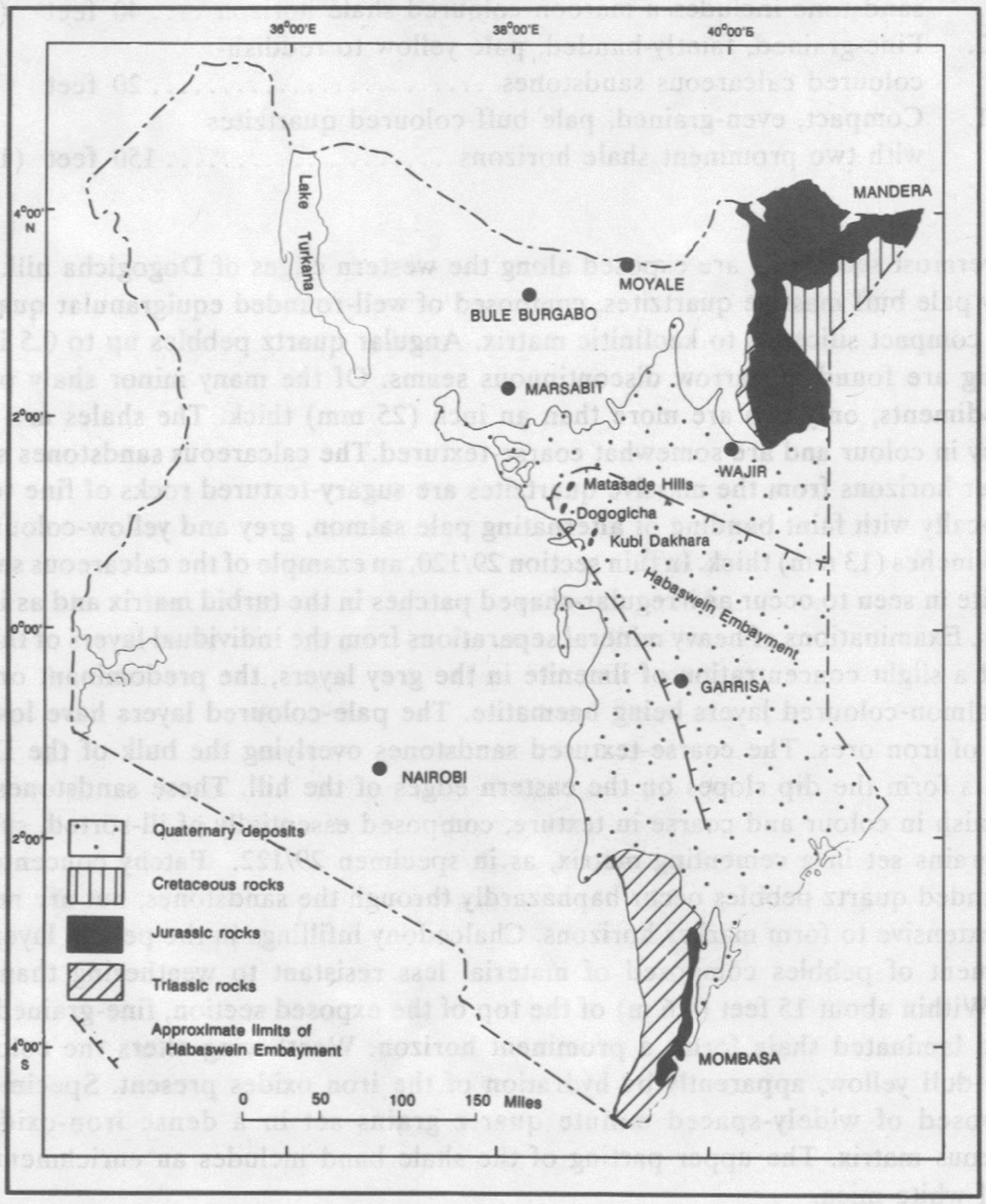


Figure 3 Sketch map showing the relationships between the Matasade and Dogogicha sediments and the known Mesozoic sediments of Kenya

For descriptive purposes the Dogogicha and Matasade sediments are considered separately.

(a) Dogogicha sediments

Dogogicha is a low-lying hill rising nearly 200 feet (61 m) above the featureless plain north of the Merti plateau. It is composed of a succession of E-dipping sandstones with calcareous and argillaceous intercalations. The succession exposed at Dogogicha is:-

3.	Coarse, gritty yellow to grey sandstones with rounded pebbles and brown chalcedonic infillings. The sandstone includes a maroon-coloured shale horizon	40 feet	(12 m)
2.	Fine-grained, faintly-banded, pale yellow to reddish-coloured calcareous sandstones	20 feet	(6 m)
1.	Compact, even-grained, pale buff-coloured quartzites with two prominent shale horizons	150 feet	(150 m)

The lowermost sediments are exposed along the western edges of Dogogicha hill. They are typically pale buff massive quartzites, composed of well-rounded equigranular quartz grains set in a compact siliceous to kaolinitic matrix. Angular quartz pebbles up to 0.5 inches (13 mm) long are found in narrow discontinuous seams. Of the many minor shaly partings in these sediments, only two are more than an inch (25 mm) thick. The shales are purple to light grey in colour and are somewhat coarse-textured.The calcareous sandstones separating the upper horizons from the massive quartzites are sugary-textured rocks of fine to medium grain, locally with faint banding of alternating pale salmon, grey and yellow-coloured layers up to 0.5 inches (13 mm) thick. In thin section 29/120, an example of the calcareous sandstones, the calcite in seen to occur as irregular-shaped patches in the turbid matrix and as interstitial infillings. Examinations of heavy mineral separations from the individual layers of this horizon revealed a slight concentration of ilmenite in the grey layers, the predominant ore present in the salmon-coloured layers being haematite. The pale-coloured layers have low concentrations of iron ores. The coarse-textured sandstones overlying the bulk of the Dogogicha sediments form the dip slopes on the eastern edges of the hill. These sandstones are grey to brownish in colour and coarse in texture, composed essentially of ill-sorted, sub-angular quartz grains set in a cementing matrix, as in specimen 29/122. Patchy concentrations of well-rounded quartz pebbles occur haphazardly through the sandstones, but are never sufficiently extensive to form marker horizons. Chalcedony infillings in the pebble layers suggest replacement of pebbles composed of material less resistant to weathering than those of quartz. Within about 15 feet (4.6 m) of the top of the exposed section, fine-grained maroon-coloured laminated shale forms a prominent horizon. Weathering alters the colour of the shale to dull yellow, apparently by hydration of the iron oxides present. Specimen 29/121 is composed of widely-spaced minute quartz grains set in a dense iron-oxide-stained argillaceous matrix. The upper parting of the shale band includes an enrichment of small flakes of white mica.

(b) Matasade sediments

About 4 miles (6.4 km) east of the north-eastern corner of the area, a group of low-lying hills, known collectively as Matasade, rises above the vast plain that stretches from the Barchuma region eastwards as far as the coast. The Matasade hills are composed of a succession of partly fossiliferous limestones, grading through a layer of calcareous siltstones into overlying sandstones (see Fig. 4).

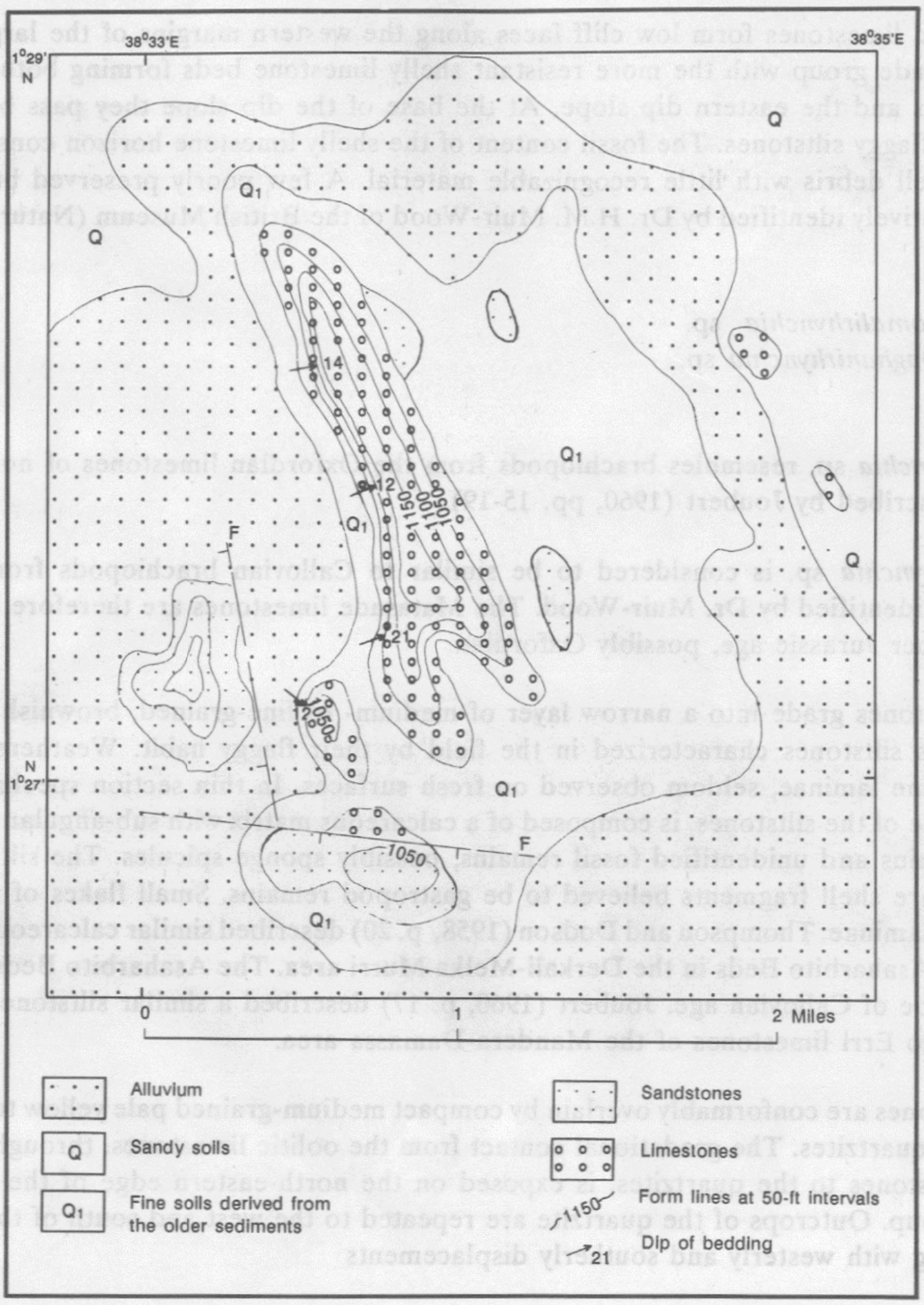


Figure 4 Detailed map of the Matasade hills

The exposed sedimentary section at Matasade is as follows:-

Compact pale grey to yellow quartzites	90	feet	(27.4 m)
Flaggy calcareous siltstones	15	feet	(4.6 m)
Yellow to drab-coloured oolitic limestones with three yellowish-brown-coloured shelly limestone horizons ..	310	feet	(94.5 m)

The oolitic limestones form low cliff faces along the western margins of the largest hill of the Matasade group with the more resistant shelly limestone beds forming both a capping to the hills and the eastern dip slope. At the base of the dip slope they pass beneath the overlying flaggy siltstones. The fossil content of the shelly limestone horizon consists mainly of fine shell debris with little recognizable material. A few poorly preserved brachiopods were tentatively identified by Dr. H.M. Muir-Wood of the British Museum (Natural History) as:-

?*Somalirhynchia* sp.
?*Daghanirhynchia* sp.

Somalirhynchia sp. resembles brachiopods from the Oxfordian limestones of north-eastern Kenya described by Joubert (1960, pp. 15-19).

Daghanirhynchia sp. is considered to be similar to Callovian brachiopods from Somalia, originally identified by Dr. Muir-Wood. The Matasade limestones are therefore believed to be of Upper Jurassic age, possibly Oxfordian.

The limestones grade into a narrow layer of medium- to fine-grained, brownish to reddish calcareous siltstones characterized in the field by their flaggy habit. Weathered surfaces develop fine laminae, seldom observed on fresh surfaces. In thin section specimen 29/142, an example of the siltstones, is composed of a calcareous matrix with sub-angular to rounded quartz grains and unidentified fossil remains, possibly sponge spicules. The siltstones also include rare shell fragments believed to be gastropod remains. Small flakes of mica occur along the laminae. Thompson and Dodson (1958, p. 20) described similar calcareous siltstones from the Asaharbito Beds in the Derkali-Melka Murri area. The Asaharbito Beds are considered to be of Callovian age. Joubert (1960, p. 17) described a similar siltstone horizon in the Muddo Erri limestones of the Mandera-Damassa area.

The siltstones are conformably overlain by compact medium-grained pale yellow to brownish-coloured quartzites. The gradational contact from the oolitic limestones, through the calcareous siltstones to the quartzites, is exposed on the north-eastern edge of the largest hill of the group. Outcrops of the quartzite are repeated to the west and south of the large hill by faulting with westerly and southerly displacements

The quartzites immediately overlying the siltstones (specimen 29/143) include small amounts of interstitial calcite. The upper layers of the quartzite are, however, free of calcite. The quartzite is composed of a mosaic of medium- to coarse-textured interlocking quartz grains, with grains of much altered felspar. Examination of heavy mineral concentrates from the quartzites established the following sequence of detrital minerals, in order of abundance: iron ore, zircon, pyroxenes, hornblende, muscovite, rutile and (possibly) tourmaline.

Correlation and age of the Dogogicha and Matasade sediments

There is little geological data indicating the stratigraphical relationship of the Dogogicha and Matasade sediments. At each of the two exposures the sediments are tilted in an approximate east-north-easterly direction, the relative position of Dogogicha suggesting that the Matasade sediments overlie the Dogogicha sandstones. As there is evidence of faulting at both hills, however, it is possible that the two hills are minor horsts, their preservation in this much-eroded region being due to upfaulting. There is little similarity between the quartzites capping the Matasade hills succession and the Dogogicha sandstones.

In the Garba Tula area, Matheson (1971) described sandstones similar to the Dogogicha sediments. The writer believes that the Dogogicha sandstones with related remnant outcrops to the south-east at Kubi Dakhara hills in the Garba Tula area may represent deltaic sedimentation along the margins of a Mesozoic basin, similar to but not necessarily contemporaneous with the Mansa Guda formation underlying the Jurassic limestones of the Bur Mayo-Tarbaj area, described by Thompson and Dodson (1960, pp. 15-18).

The Matasade limestones can be roughly correlated with the Callovian-Oxfordian limestones of North-Eastern Kenya. The Muddo Erri Limestones described by Joubert (*loc. cit.*) locally include bands of brown oolitic shelly limestone and calcareous siltstones, lithologically comparable with the Matasade beds. Correlation with the Oxfordian limestones of the Mandera area does not imply a direct connection between the two localities, but, rather, similar conditions of deposition and sedimentary environment. Arkell (1956, p. 320) observed that in spite of a lack of continuity of outcrops there is little doubt that the Upper Jurassic sediments of the coastal belt were formed in direct marine communication with those of Jubaland (i.e. the region south of latitude 6° N, including the Jurassic sediments of Kenya and surrounding countries) and the Trans-Erythraean trough.

Since completion of the present report, another occurrence of sandstone lithologically similar to the Dogogicha sediments has been recorded by Dodson and Matheson (Report No. 94, in press). These sandstones form an isolated hill Bule Burgabo, protruding through Pleistocene lavas in the Marsabit district. Relationships between either the Dogogicha sandstones or the Mansa Guda sandstones and the Bule Burgabo sediments are not clear as much of the intervening area is covered by Pleistocene to Recent lavas and superficial deposits. Considering these sediments as contemporaneous, it is possible that the Habaswein embayment extends in a north-westerly direction to include the Bule Burgabo area. Alternatively, it may be that the sediments of the Wajir area extended much farther westward than their present boundaries indicate.

The history of the Jurassic sedimentation of Eastern Africa has been described by Thompson and Dodson (1958, p. 22; 1960, p. 33), Joubert (1960, p. 53) and several other writers. It is agreed that the Lower Jurassic sediments were deposited in a rapidly-encroaching Jurassic sea, in the shallow-water environment of a foreland trough. After a period of relative stability, during which most of the fossiliferous limestones of mid-Jurassic age were deposited, marine regression took place. The sediments deposited at this stage included a variety of sandstones, shales and argillaceous limestones. During the Cretaceous period sandstones and shales were deposited in north-eastern Kenya.

The Dogogicha sandstones are probably the littoral deposits of an encroaching sea, while the Matasade limestones represent shallow sea deposits as shown by the presence of oolites and the fragmentary condition of the fossil shell content. Later, as the Jurassic sea retreated, the Matasade sandstones were deposited over the limestones. The Mesozoic sediments of the present area were probably deposited in an embayment or shallow basin at the margins of the Jurassic foreland trough.

(2) Sedimentary rocks of Tertiary age

Merti Beds

Sediments form the bulk of the geological succession of the Merti and Barchuma plateaux. Their continued existence is due to protection afforded by remnants of lava flows capping the sediments and their foundation of 'Basement System' rocks. On the western and south-western margins of the Merti plateau the lava cap directly overlies 'Basement System' rocks. The Sukela plateau is composed almost entirely of 'Basement System' rocks, with only a thin wedge of sediments beneath the lava cap on the north-eastern edge of the plateau. The Merti Beds are considered to be infillings of a depression in an eroded surface of meta-sediments. There is no indication of the maximum thickness attained by the sediments either at Merti or Barchuma, the thickest exposed section being about 320 feet (97 m). As the sediments, with local exceptions, tend to thicken north-eastwards, it is possible that the maximum thickness may exceed 500 feet (152 m).

The beds are typically coarse-textured deltaic deposits, composed essentially of sandstones, conglomerates and gravels. Good exposures of sediments are rare as most of the plateau slopes are littered with lava boulders.

A typical section measured on the western edge of Merti is as follows:-

8.	Olivine basalt cap	25 feet	(7.6 m)
7.	Reddish conglomerate with calcareous matrix	17 feet	(5.2 m)
6.	Blotchy yellow to reddish calcareous grits with abundant calcareous nodules	8 feet	(2.4 m)
5.	Whitish fine-grained kaolinitic sandstones	45 feet	(13.7 m)

4.	Pale yellow, compact, medium-grained sandstones	15 feet	(4.6 m)
3.	Dark maroon gritty sandstones	12 feet	(3.7 m)
2.	Pale yellow, fine-grained, ill-consolidated kaolinitic sandstones	40 feet	(12.2 m)
1.	Drab-coloured gritty sandstones with calcareous nodules and abundant concretionary rods (possibly replacement of original vegetable matter)	183 feet	(55.8 m)
	Total	345 feet	(105.2 m)

A section measured on the north-eastern slopes of Barchuma plateau is as follows:-

6.	Olivine basalt cap	33 feet	(10.1 m)
5.	Reddish-brown nodular secondary limestone	5 feet	(1.5 m)
4.	Brownish ill-sorted coarse-textured grits	7 feet	(2.1 m)
3.	Pale yellow kaolinitic sandstones with abundant pinkish calcareous nodules and concretionary rods	20 feet	(6.1 m)
2.	Whitish kaolinized felspathic sandstones with intercalated gritty horizons. Rare calcareous nodules towards the upper part of the horizon	45 feet	(13.7 m)
1.	Pale mauve to whitish coarse-textured sandstones with narrow conglomeratic layers towards the lowermost part of the exposed strata	190 feet	(57.9 m)
	Total	300 feet	(91.4 m)

The two type sections described are representative of the sediments exposed at Merti, Barchuma, and on the slopes of the smaller hills between the Sukela and Barchuma plateaux. The Merti Beds are therefore made up of a series of coarse-textured arenaceous to rudaceous sediments, characterized by a high kaolin content and an abundance of calcareous material both as a cementing medium and as concretionary nodules or rods. Microscopic examination of heavy mineral concentrates from the sediments proved that the Merti Beds were derived mainly from 'Basement System' rocks, but appear to have been transported for considerable distances. The percentages of heavy minerals in the Merti Beds is roughly a quarter of the concentration in typical nearby 'Basement System' gneisses.

A thorough search for fossils proved unsuccessful. Several large, and in some cases elongated, calcareous nodules had shapes suggestive of mammalian bones, and in three such nodules a spongy, bone-like texture is present. Staff members of the British Museum (Natural History) reported, however, that no fossil material is present in these samples. The abundant rod-like concretions of calcareous and, rarely, siliceous composition found in certain horizons of the beds, give the impression of crude replacement of original vegetation material. The effect is heightened by branching of the rods and their tubular construction. Microscopic examination of several sections cut through the stem-like rods failed to reveal the presence

of identifiable cellular texture. It is of interest to record that the rod-like concretions were invariably pink to light brown in colour even when included in white kaolinitic sandstones.

The Merti sediments bear no resemblance to the Miocene sediments of north-western Kenya, described by Shackleton (1946, p. 27) and Dixey (1948, p. 20). Although there is little similarity between the Massinini sediments of the North Kitui areas, described by Dodson (1955, p. 20) and the Merti Beds, they may well be contemporaneous, both having been laid down during a late-Tertiary to early-Pleistocene pluvial period.

6. VOLCANIC ROCKS

Remnants of a former lava sheet cap the Merti, Sukela and Barchuma plateaux. The lavas originated from a volcanic pile to the south of the present area, flowing out over a surface sloping north-eastwards at approximately 15 feet (4.5 m) per mile. Many feeder dykes and a few plugs occur in the area. The flows vary in thickness from a few inches to about 30 feet (9 m), where a single flow alone forms the lava cap. Individual patchy lava flows (see geological map) resting on the plateau surfaces are believed to have been extruded through local fissures or minor vents.

The lava exhibits only slight textural and mineral variations between the individual flows making up the compound sheet. Typically, it is a medium-textured porphyritic basalt, rich in olivine and pyroxene. The basalt is frequently vesicular but amygdaloidal infilling is rare. A typical example of the basalt, specimen 29/17 from north-eastern Barchuma, is a coarse-grained vesicular augite-basalt, composed of sub-ophitic labradorite laths with abundant neutral-coloured augite, subhedral olivine marginally replaced by iddingsite, and irregular to idiomorphic grains of ore. In 29/46, from the lowermost flow at the southern margin of Sukela plateau, the basalt is composed of a fine-grained groundmass of neutral-coloured augite, laths of labradorite and abundant idiomorphic grains of ore, with medium-sized idiomorphic olivine phenocrysts. The olivine is patchily replaced by iddingsite. Specimen 29/138, from a younger lava flow on the western edge of the Merti plateau, is of slightly coarser texture than 29/46, but is generally similar in composition.

Two volcanic plugs of analcime basalt on the central Sukela plateau are unrelated to the olivine basalts. They may belong to a volcanic phase entirely separated from the plateau lava outpourings, or alternatively they may be representative of the closing phase of the volcanism, their alkaline composition being a product of magmatic differentiation. Specimen 29/44, from the more northerly of the plugs, is a coarse-textured, porphyritic, dark bluish-grey rock, speckled with phenocrysts. The groundmass is composed of analcime, pyroxene, iron ore and small flakes of reddish-brown biotite. The phenocrysts are medium-sized idiomorphic grains of olivine, and pale greenish to neutral-coloured augite. The pyroxenes are crowded with minute inclusions of iron ore, orthopyroxene(?) and a few small granules of olivine. Plagioclase (An_{55}) forms rare microphenocrysts with somewhat corroded margins. The other plug (specimen 29/45) is composed largely of scoriaceous material with patches of aphano-

phyric lava. Microscope examination reveals that this rock is composed of a fine-grained groundmass in which aggregates of somewhat larger analcime grains can be identified. Olivine phenocrysts have dense opaque marginal reaction rims, the pyroxenes exhibiting marginal resorption to varying degrees.

7. SUPERFICIAL DEPOSITS

The greater portion of the area is covered by superficial deposits of sands, soils and weakly-consolidated sediments. In many regions the soils are obviously derived from the underlying rock, but in the central and north-eastern parts of the area the mantle of superficial deposits attains a considerable thickness, effectively obscuring the identity of the underlying rocks. Most of the eastern part of the area is covered by reddish-brown sandy soils composed essentially of coarse-textured, somewhat rounded quartz grains, mostly with a patchy film of reddish-coloured iron-oxide staining. In the Dogogicha area these deposits grade into whitish, well-sorted sands locally heaped up to form small dunes.

In the northern part of the area the Matakone river course opens out into a shallow valley choked with alluvium. The alluvium is typically fine-textured and grey in colour, but as the valley broadens out to form extensive alluvial flats in the Matasade hills area, it grades into a coarser-textured dull brown soil.

Deposits of fine-textured white kaolinitic sands along the edges of the Barchuma and Merti plateaux are believed to have been derived from the Merti sediments. The greatest thickness of these sands was observed on the northern margin of the Merti plateau, where a maximum of just over 20 feet (6 m) of white sand overlies the stratified Merti Beds. Elsewhere the sands are patchy.

A residual mantle of dark grey soils covers much of the area known to be occupied by plutonic rocks and related ortho-amphibolites. The soils are composed almost entirely of the weathered products of the plutonic rocks, the dark grey colour being due to a high proportion of hornblende, pyroxene and iron ore.

Calcrete (kunkar limestone) is developed at several minor localities in the area. It occurs as a highly irregular encrustation or cap overlying calcium-rich rocks, such as limestones or amphibolites. Concretionary nodules of secondary limestone are found in some of the fine soils and alluvium.

Consolidated valley deposits were found in three places in the Nyachissa valley, between Dakadima hill and Nyachissa waterhole. The sediments attain a maximum thickness of just over 20 feet (6 m) and rest directly on 'Basement System' rocks. They are composed of coarse-textured quartzose sands or gravels, cemented in a fine dark reddish-brown argillaceous matrix. Unidentifiable fragments of what appear to be gastropod shells were found in the upper part of one of the exposures of these deposits.

VI. METAMORPHISM

The problem of the metamorphic history of the 'Basement System' of Kenya has received much attention in previous geological reports. It is generally agreed that the 'Basement System' is the product of regional metamorphism on a geosynclinal scale, resulting in the conversion of original arenaceous, argillaceous and calcareous sediments into metamorphic rocks of psammitic, semi-pelitic and calcareous composition.

It is assumed that during the late stages of orogenesis the metasediments were subjected to granitization, a complex process involving the metasomatic introduction of alkalis. The degree of metasomatic conversion of various rock types is largely dependent on their original composition and, to a lesser extent, their original texture. Thus the calcareous rocks such as limestones are generally not affected by metasomatism, while rocks such as biotite gneisses exhibit a high degree of metasomatic influence, shown by the presence of the potash felspar microcline, both in the replacive intergranular form and as porphyroblasts.

The degree of metamorphism attained by the 'Basement System' rocks is assessed by comparison with the idealised mineral assemblages of regional metamorphosed rocks as described by Turner (Fyfe *et al.*, 1958, pp. 215-239). Typical mineral assemblages of the 'Basement System' rocks in the present area are:-

Pelitic and quartzo-felspathic assemblages:-

Quartz-microcline-sillimanite-plagioclase-muscovite
Quartz-sillimanite-almandine-plagioclase-biotite.

Calcareous assemblages:-

Calcite-garnet-diopside-quartz-plagioclase
Calcite-garnet-diopside-hornblende-epidote.

Basic assemblages:-

Hornblende-plagioclase-diopside
Hornblende-plagioclase-biotite.

It is concluded that the most intense metamorphism to which the 'Basement System' and plutonic rocks of the Barchuma-Kom area were subjected, coincides with a sub-stage between the staurolite-quartz sub-facies and the sillimanite-almandine sub-facies of the almandine-amphibolite facies. In the calc-silicate granulite specimen No. 29/85, the essential mineral constituents are bytownite, quartz and epidote. Kennedy (1949, p. 50) concluded that calc-silicate granulites in the Moine schists of Scotland occur in zones of progressive meta-

morphism, the end-products containing bytownite, to the exclusion of other plagioclase or orthoclase. He considered those granulites to lie within the amphibolite and pyroxene-hornfels facies of Eskola.

Hitherto only the effects of regional metamorphism have been considered. In view of the magnitude of the Dalecha plutonic body, part of which is included in the area, there is little doubt that an aureole of contact metamorphism was formed during intrusion into the 'Basement System' rocks. There is ample evidence however to show that a phase of regional metamorphism followed the plutonic intrusion, obscuring the effects of the original contact metamorphism in the 'Basement System' country rock.

VII. STRUCTURE

The following is considered to be the main sequence of events in the structural evolution of the area (see Fig. 5):-

(a) 'Basement System' orogeny, culminating in the formation of north-south trending folds;

(b) intrusion and subsequent folding of the Dalecha plutonic rocks;

(c) downwarping of the Habaswein embayment, during the Mesozoic era.

1. FOLDING

For convenience, the structures of both the 'Basement System' rocks and the Dalecha plutonic rocks are considered together. In order of occurrence from west to east, the following are the major fold structures of the oldest exposed rocks in the area.

The Kom syncline

A tight, closed fold plunging southwards in the Kom area. North of the Sukela Plateau, what appears to be an extension of the Kom syncline plunges gently to the north. Besides the major curvature of the fold axis there is evidence of minor undulations. Along the trace of the fold axis lineation plunge varies from about 23° southwards to about 53° northwards. Curving lineations were observed at two rock exposures.

West of the Kom syncline a small overturned anticlinal fold is followed by a closed synclinal fold. The axial trace of the syncline is aligned roughly along the western boundary of the area. East of the Kom syncline the foliae are folded around the massive dome-like slab of

Kitio, into a compact anticline and syncline double fold. The minor axes occur along a north-westerly aligned plane.

The Kom anticline

Tight folds of the anticline are clearly exposed in the Kom valley. Northwards in the Solberawawa valley the fold axis curves from a gentle southerly inclination to an approximate northerly plunge.

The Solberawawa syncline

East of Kom, this fold has a gentle southerly plunge, steepening progressively to where there is an apparent 'cut-off' by the western margin of the Dalecha plutonic mass. Near Solberawawa waterhole the fold axis is nearly horizontal. Two small folds with northerly plunging axes occur between this fold and the following anticline.

The Solberawawa anticline

Like the syncline, the Solberawawa anticline plunges gently to the south in the area between the Kom and Solberawawa valleys, the plunge steepening considerably in the Dakadima area, near the contact with the Dalecha plutonic rocks.

In the few exposures of 'Basement System' rocks along the south-eastern margin of the Dalecha plutonic mass, the rocks dip towards the plutonic intrusion, in an approximate north-westerly direction. Farther eastward, near the Merti plateau, 'Basement System' rocks follow the approximate north-south structural trend of the Kom region.

Folding of the Dalecha plutonic rocks is less easy to recognise. The noritic rocks form heaps of bouldery outcrops, while the metamorphosed ortho-amphibolites are mostly eroded to a soft friable condition, seldom retaining recognisable foliation planes. The main fold in the plutonic mass is a syncline, the trace of the fold axis curving from an approximate east-west direction in the Kubi Dukessa area to an approximate north-easterly direction in the Chabich area. Two smaller but more clearly defined folds follow the main syncline, the trace of the anticlinal fold axis passing just south of Dalecha peak. East of Chabich, along the southern boundary of the area, layers of noritic rock are impressively folded into a tight anticlinal and synclinal fold. Dark and light-coloured layers of rock, including anorthosite bands, follow the folding.

Conclusions

The 'Basement System' rocks are folded in a roughly north-south trend conforming with the predominant structural trend (see insets 1 and 2, Fig. 5). The folding is characterised by curvature of the major fold axes from an approximate southward plunge to a northerly plunge. In addition there is evidence of undulations of the fold axes within the major curvature, a condition resulting from secondary folding either contemporaneous with, or subsequent to, the major phase of folding. The writer believes that at least some of the secondary folding is the result of buckling of the major north-south folds on lateral elongation under extreme pressures. Evidence for this is provided by the orientation of five minor cross fold axes measured, in each case aligned normal to the local ß-lineation. Williams (1966) described

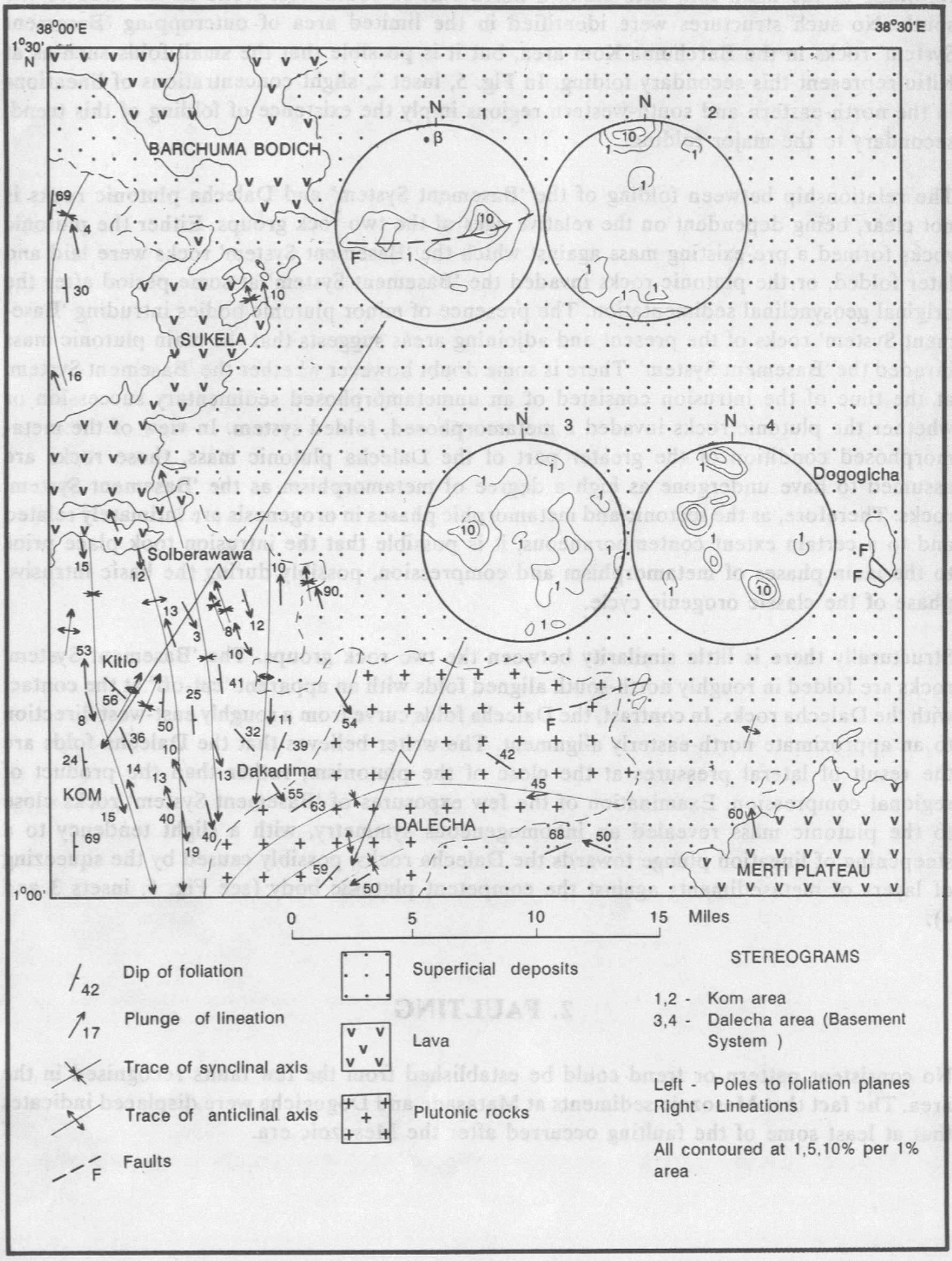


Figure 5 Structural map of the Barchuma-Kom area

refolding of the main fold axes along a north-east to south-west trend in the area to the south. No such structures were identified in the limited area of outcropping 'Basement System' rocks in the Barchuma-Kom area, but it is possible that the small folds such as at Kitio represent this secondary folding. In Fig. 5, inset 2, slight concentrations of lineations in the north-eastern and south-western regions imply the existence of folding of this trend, secondary to the major folding.

The relationship between folding of the 'Basement System' and Dalecha plutonic rocks is not clear, being dependent on the relative ages of the two rock groups. Either the plutonic rocks formed a pre-existing mass against which the 'Basement System' rocks were laid and later folded, or the plutonic rocks invaded the 'Basement System' at some period after the original geosynclinal sedimentation. The presence of minor plutonic bodies intruding 'Basement System' rocks of the present and adjoining areas suggests that the main plutonic mass invaded the 'Basement System'. There is some doubt however whether the 'Basement System' at the time of the intrusion consisted of an unmetamorphosed sedimentary succession or whether the plutonic rocks invaded a metamorphosed, folded system. In view of the metamorphosed condition of the greater part of the Dalecha plutonic mass, those rocks are assumed to have undergone as high a degree of metamorphism as the 'Basement System' rocks. Therefore, as the tectonic and metamorphic phases in orogenesis are intimately related and to a certain extent contemporaneous, it is possible that the intrusion took place prior to the main phases of metamorphism and compression, possibly during the basic intrusive phase of the classic orogenic cycle.

Structurally there is little similarity between the two rock groups. The 'Basement System' rocks are folded in roughly north-south aligned folds with an apparent 'cut-off' at the contact with the Dalecha rocks. In contrast, the Dalecha folds curve from a roughly east-west direction to an approximate north-easterly alignment. The writer believes that the Dalecha folds are the result of lateral pressures at the close of the plutonism, rather than the product of regional compression. Examination of the few exposures of 'Basement System' rocks close to the plutonic mass revealed an inhomogeneous symmetry, with a slight tendency to a steepening of lineation plunge towards the Dalecha rocks, possibly caused by the squeezing of layers of metasediments against the competent plutonic body (see Fig. 5, insets 3 and 4).

2. FAULTING

No consistent pattern or trend could be established from the few faults recognised in the area. The fact that Mesozoic sediments at Matasade and Dogogicha were displaced indicates that at least some of the faulting occurred after the Mesozoic era.

VIII. ECONOMIC GEOLOGY

Less than half of the Barchuma-Kom area is occupied by outcropping rock, the bulk of the solid rock being obscured by superficial deposits. The 'Basement System' is represented by a succession of metamorphosed sediments extensively intruded by pegmatite veins. Although some of the pegmatites are large, they are devoid of mineralization of potential value. Copper ores are present in a granulitic rock of the 'Basement System' but the mineralization is obviously related to the nearby Dalecha plutonic rocks. A few pegmatites containing mica intrude the plutonic rocks.

Oil

The possibility of discovering oil in the Mesozoic rocks of the Northern Province of Kenya has been discussed in several reports describing the geology of areas in the Wajir and Mandera districts. The Mesozoic sediments forming the Dogogicha and Matasade hills in the present area are of interest as their presence has hitherto been unknown. Their situation in relation to known Jurassic sediments, shown in Fig. 3, suggests that they were laid down in a sedimentary basin or embayment, referred to earlier by the writer as the Habaswein embayment. The established existence of the Basin has significance, as investigation is likely to prove a progressive accumulation of sediments towards the centre of the embayment.

Copper

About two miles north-east of Chabich hill a granulitic rock contains copper enrichment. The mineralization is however limited to an area of about eight feet long and two feet wide. The copper minerals present are mainly bornite and the secondary carbonate malachite, with small amounts chalcopyrite and azurite. A chemical assay of the most intensely mineralized portion of the granulite proved a content of 16.6% copper. Examination of nearby gabbroidal and noritic rocks revealed the presence of small amounts of chalcopyrite and rare malachite.

Excavation of a trench across the enriched granulite proved that the mineralization is isolated, extending below the surface for little more than three feet. Williams (1966, p. 49) reported other patchy copper mineralization in the southerly extension of the plutonic rocks. Thus, while there is a faint possibility that exploitable copper ore may exist within the plutonic body, there are insufficient signs of mineralization on the surface to encourage further prospecting.

Mica

Several pegmatites intruding the plutonic rocks south of Kubi Dukessa contain muscovite. The mica books reach up to several inches across but are seldom free of spotting or waviness. Careful search may reveal the presence of better quality material.

Other minerals

Examination of alluvial heavy mineral concentrates collected from the Kom, Muddo Gali, and several small sand rivers draining the Dalecha area, failed to reveal the presence of any of the valuable minerals sometimes associated with plutonic rocks other than magnesite, which occurs in thin veinlets in peridotites and serpentinites near Dalecha beacon.

Water

In relation to the available grazing, water supplies are adequate in western and southern parts of the area. Permanent water can be obtained at certain points in the Matakone, Solberawawa, Kom and Muddo Gali sand rivers. Except for the semi-permanent Bambata waterhole, no permanent water supplies are available in the central and eastern portions of the area. To increase water supplies, small dams might be constructed in the rocky valleys between Kom and the Merti plateau. Shallow wells dug in the superficial deposits marginal to the outcropping rock would probably yield permanent water in some localities.

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